FAA-ADS-40

HELICOPTER NOISE CHARACTERISTICS FOR HELIPORT PLANNING

TECHNICAL REPORT

March 1965

by

Dwight E. Bishop

Bolt Beranek and Newman Inc.
15808 Wyandotte Street
Van Nuys, California 91406

Under Contract FA64WA-4949

for

FEDERAL AVIATION AGENCY

AIRCRAFT DEVELOPMENT SERVICE

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ABSTRACT

Noise data and simplified procedures are presented for estimating the perceived noise levels produced by current civil and military helicopters (piston- and turbine-powered) during takeoff, landing, flyover and hover operations. Noise data and procedures are also presented for comparing helicopter noise with other vehicle noise and with ambient noise found in typical urban and suburban areas. The procedures permit an assessment of the compatibility of helicopter noise with typical land uses near heliports.

Generalized helicopter noise data are presented in the form of noise contours and in perceived noise level-vs-distance charts for different helicopter categories. The generalized noise charts are based upon measurements of a number of military and civil aircraft. Analysis of these measurements, discussed in Appendix A, shows that:

a) for most helicopters the spread in perceived noise levels for takeoff, landing, flyover and hover operations is of the order of 5 PNdB or less, a spread in noise levels much less than encountered for fixed-wing aircraft.

b) piston-powered helicopters are noisier than turbine-powered helicopters of comparable size. No consistent difference in noise levels between single and dual rotor helicopters was noted.

c) perceived noise levels for turbine-powered helicopters show greater changes with size of aircraft than do noise levels for piston-powered helicopters.

d) for planning purposes, noise radiation from helicopters can be assumed to be non-directional in both vertical and horizontal planes.

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I. INTRODUCTION

This report presents technical information and procedures for estimating the noise levels produced by current civil and military helicopters (piston- and turbine-powered) during varied flight and ground operations.* Information and procedures are also presented for comparing helicopter noise with other vehicle noise, and with ambient noise found in typical urban and suburban areas. These procedures permit an assessment of the extent to which helicopter noise is compatible with typical land uses (residential, commercial, industrial, etc.) in areas near heliports.

Noise data and procedures are presented in simplified fashion. The information may be readily used by those without specialized acoustical training but who are concerned with the location and development of a heliport, or with land planning or land zoning in the vicinity of heliports.

In recent years considerable study has been devoted to the measurement and analysis of aircraft noise, and in assessing the effects of aircraft noise on people. This report draws extensively upon methods of analyses originally developed for evaluating noise from fixed-wing aircraft. In particular, this report is based upon procedures developed for estimating the community response of residential areas exposed to aircraft noise and upon allied procedures for estimating the compatability of aircraft noise with different land uses.[1,2]**

A prime advantage of the helicopter is its ability to climb and descend at very steep gradients, thus permitting its operation in and out of small landing areas close to built-up commercial, industrial or residential areas. One key to future growth of steep-gradient aircraft is an expanding

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* This report does not consider helicopters powered by rotor-tip propulsion systems, or other types of V/STOL aircraft.

** The noise level information presented in this report may be used, without modification, to supplement the limited helicopter noise information presented in References 1 and 2.

availability of close-in and downtown landing areas convenient to users of the aircraft. However, this flexibility in operation and ability to operate close to developed areas may create a number of noise problems. These problems arise from the intrusion of helicopter noise into surrounding areas and the effects of such noise intrusion on human activities.

The noise produced by current helicopters is much less than that produced by large civil jet aircraft, when judged in terms of noise levels produced at similar distances or in terms of total noise energy created. However, helicopters often operate in areas that are not exposed to noise associated with aircraft operations. Hence helicopter noise intrusion in urban areas can be comparable with that produced by fixed-wing aircraft in land areas near airports.

The procedure outlined in this report for determining helicopter noise compatibility contains five steps. These steps are listed in Fig. 1. Each step is described in the report together with one or more examples to illustrate its application. Preceding the discussion of the procedures, Section II describes the methods for determining the noise levels expected from helicopter operations. Section II, therefore, provides the basic noise information needed for Step 2 in the procedure. Appendix A discusses in more detail some of the analyses procedures, sources of information and the detailed noise information from which the generalized presentation of helicopter noise, given in Section II, has been derived.

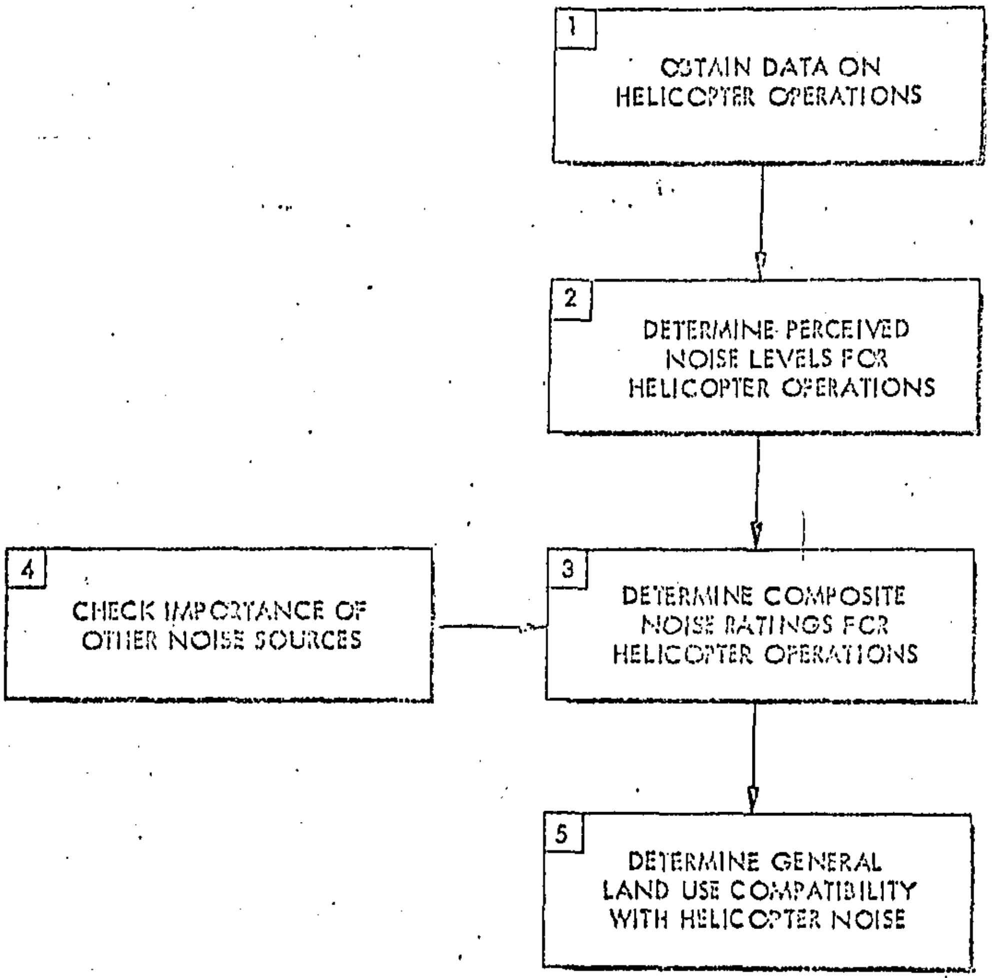


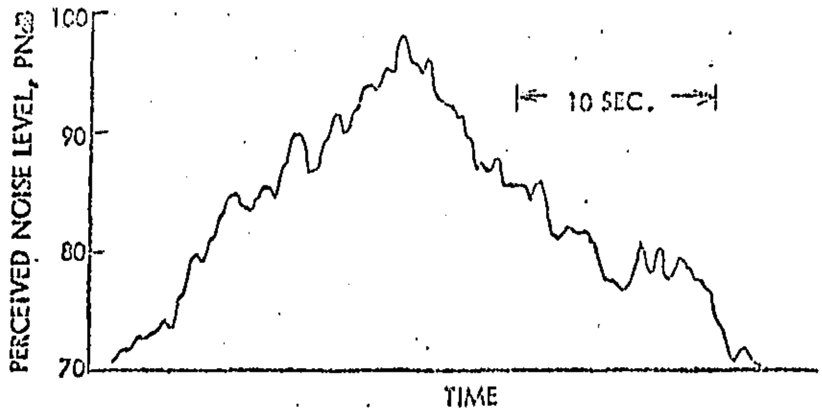
FIGURE 1. STEPS IN PROCEDURES FOR EVALUATING LAND USE COMPATIBILITY WITH HELICOPTER NOISE

II. DESCRIPTIONS OF HELICOPTER NOISE

A. Perceived Noise Level

Throughout this report, helicopter noise as well as noise from other sources will be described in terms of the perceived noise level expressed in PNdB. The perceived noise level is a quantity calculated from physical measurements of the noise that correlates very well with the subjective evaluation of the noisiness or annoyance of various types of noise. It has become a widely accepted means for describing aircraft noise both in this country and abroad. Procedures for calculating perceived noise levels are summarized in Attachment 4 of Reference 1 and in Reference 3.

Generally, the noise produced by a flight operation (takeoff, landing or level flight flyovers) is described in terms of the maximum perceived noise level observed on the ground during the operation. The sketch below shows a typical time record of the perceived noise level during flyover of a small piston helicopter.



For the particular time history shown in the sketch, the noise level can be summarized in terms of the maximum level, 98 PNdB.

The sketch also illustrates a typical characteristic of aircraft and motor vehicle noise, the rapid change in noise levels with time. This distinction between noise levels which are continuous, or nearly so, and noise levels that change rapidly with time becomes important in assessing the relative annoyance or interference from the noise. It results in the need to take into account the number of times the intermittent or rapidly changing noise occurs in a given time period. This factor is introduced later in Step 3 of the compatibility procedure.

B. Perceived Noise Level Curves For Helicopters

One simplifying factor in describing helicopter noise is the fact that for most helicopter operations (takeoff, landing, cruise and hover) noise levels vary over a relatively narrow PNdB range. Thus one curve showing the variation in perceived noise level with distance will suffice for describing all types of operations for a given helicopter.*

The noise level produced by current civil and military helicopters can be estimated from the four curves shown in Fig. 2. The curves show the variation in perceived noise

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* Exceptions exist for some specific types of aircraft and for special operational conditions, autorotation descents, for example, or maneuvers where main rotor "blade slap" (described as a loud "popping" or "cracking" sound) occurs. However, for many helicopters, the spread in noise levels for various routine flight operations is 5 PNdB or less. For a fixed-wing aircraft, the variation in perceived noise levels between takeoff and landing is typically 15 to 20 PNdB.

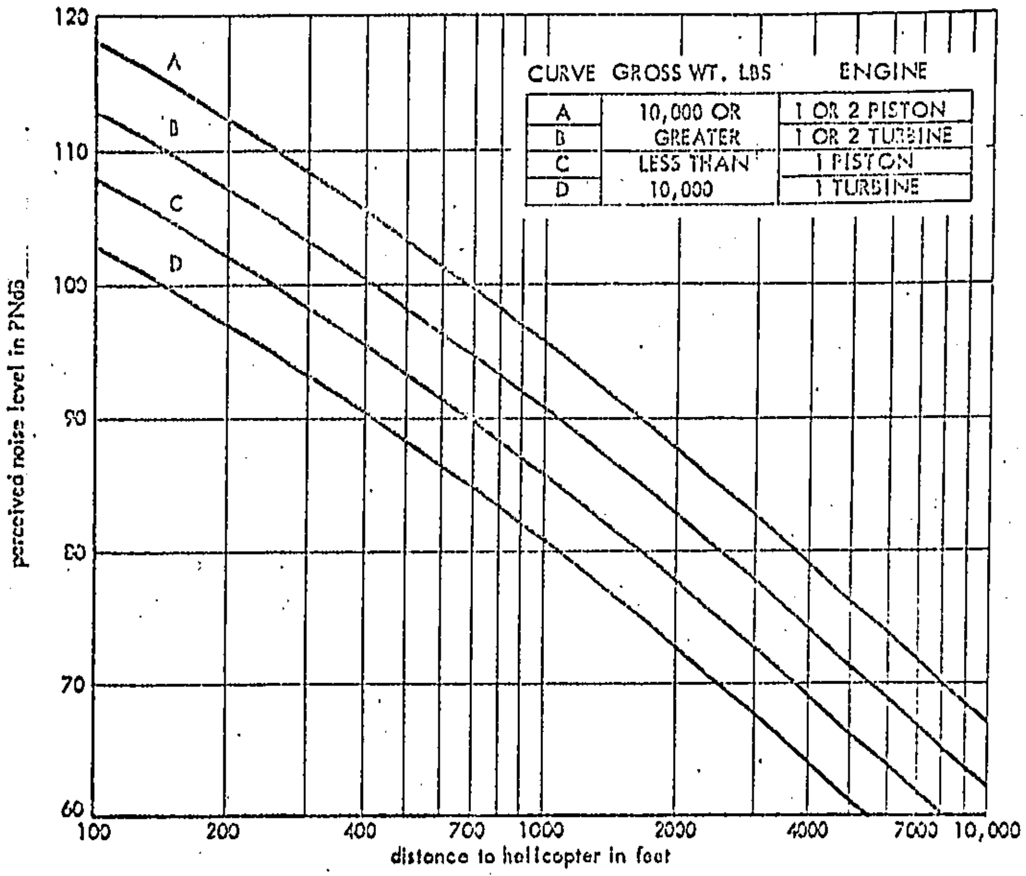

FIGURE 2. VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR HELICOPTERS

level with distance from the aircraft to the observer for four classes of helicopters.*

a) large, one or two engine piston-powered helicopters

b) large, one or two engine turbine-powered helicopters

c) small and medium, single engine piston helicopters

d) small and medium, single engine turbine helicopters.

The curves in Fig. 2 are spaced approximately 5 PNdB apart. They apply for takeoff, landing, flyover and hover operations.

The curves of Fig. 2 are for air-to-ground transmission of noise. For engine runups, hovering in ground effect, or for flight operations where the aircraft is at a low angle of elevation (approximately 5° or less), noise levels at large distances from the aircraft will generally be lower than indicated by Fig. 2. For such "ground-to-ground" noise transmission conditions the perceived noise level-versus-distance curves of Fig. 2 should be reduced, using the correction values shown in Fig. 3.

Figure 2 (with Fig. 3 as required) permits estimation of the perceived noise levels at various distances from the aircraft. Figure 2 may therefore be used to estimate noise levels directly under a flight path. Figure 2 and Fig. 3 may also be used directly to estimate noise levels at any given distance for a helicopter hovering close to the ground.

For example, for a large turbine-powered helicopter flying directly overhead at an altitude of 1000 ft, we find from Fig. 2 that the maximum perceived noise level occurring during the flyover is 91 PNdB.

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* Large is here used to indicate an aircraft of 10,000 lbs normal gross weight or more. Small and medium refers to helicopters of less than 10,000 lbs normal gross weight.

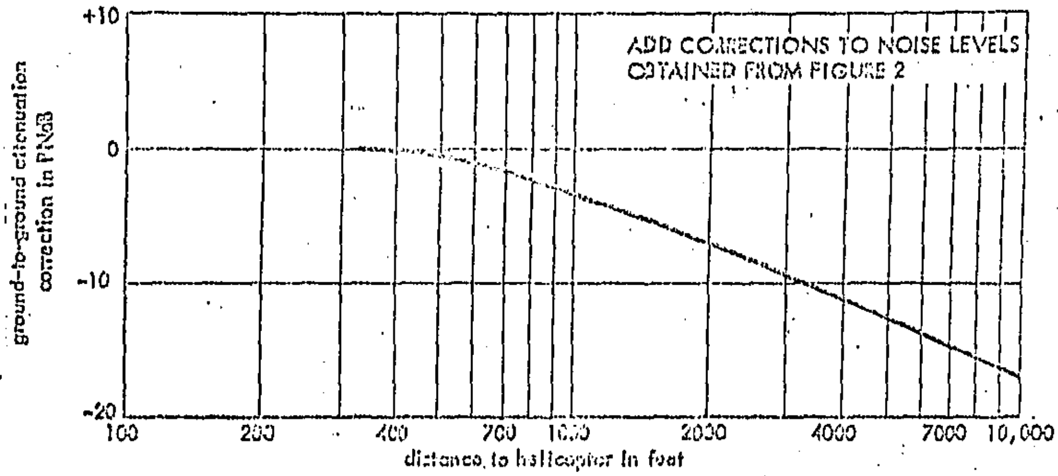


FIGURE 3. HELICOPTER NOISE CORRECTION FOR GROUND-TO-GROUND NOISE TRANSMISSION

At a horizontal distance of 800 ft from a small piston-powered helicopter hovering a few feet above the ground, Fig. 2 shows a perceived noise level of 89 PNdB. Figure 3 gives a correction for ground-to-ground transmission of -2 PNdB. Thus the estimated level at 800 ft horizontal distance is (89 - 2) PNdB, or 87 PNdB.

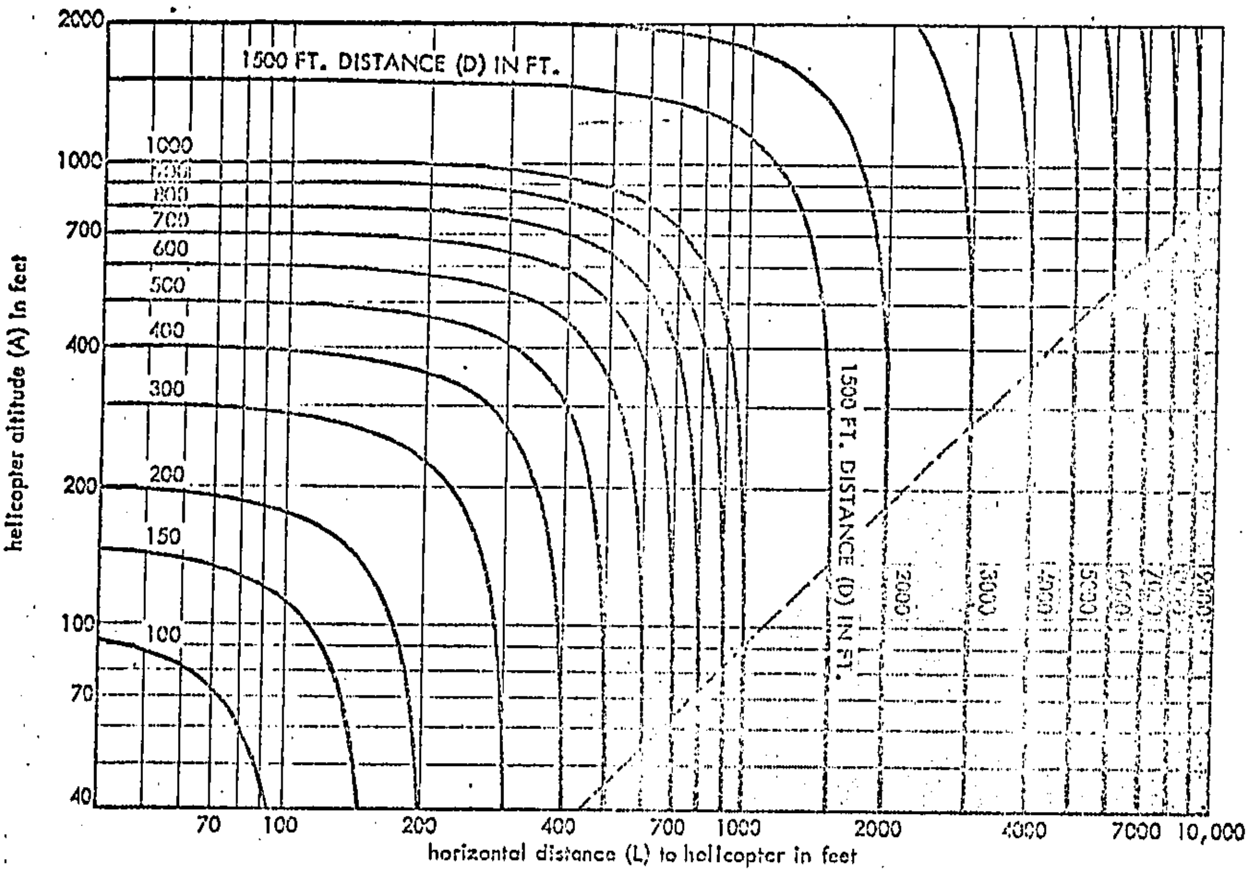
For positions off to one side of the flight path the procedure for determining noise levels is slightly different. One must determine the lateral distance from the flight path to the ground position and the altitude of the helicopter. These two distances form the sides of a right triangle with the desired distance being the hypotenuse of that triangle. For this distance one can determine the corresponding perceived noise level from the appropriate perceived noise level-vs-distance curve.

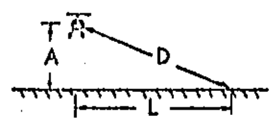
To aid in such distance calculations, Fig. 4 has been prepared. It gives directly the approximate distance to the aircraft for a range of altitude and horizontal distance combinations. The shaded area in Fig. 4 also indicates when the corrections for ground-to-ground noise attenuation from Fig. 3 are needed.

For example, if we wish to find the perceived noise level at a position 2000 ft to one side of the flyover path flown by a small piston-powered helicopter at an altitude of 1000 ft, we enter Fig. 4 with the altitude and horizontal distance information and find that the approximate distance to the aircraft is 2700 ft. Reference to Fig. 2 shows that the perceived noise level is 74 PNdB.

C. Development of Noise Contours

The maximum levels occurring during a flight operation can often be conveniently described in terms of noise contours showing the maximum levels occurring on the ground at positions beneath and to either side of the flight path. Such contours are used extensively for depicting the noise levels produced by fixed-wing aircraft on landing or taking off.1,2/ In planning, it is desirable to use generalized contours which permit one to estimate the noise





ADD NOISE ATTENUATION CORRECTION FROM FIGURE 3

FIGURE 4. CHART FOR CALCULATING DISTANCE TO HELICOPTER FROM ALTITUDE AND HORIZONTAL DISTANCE INFORMATION

produced by operations by any of several classes of aircraft.

The major steps in developing a contour for an aircraft takeoff are illustrated in Fig. 5. Needed information includes a graph, or table, showing the perceived noise level as a function of distance between the aircraft and observer, and a flight profile which specifies the aircraft altitude in terms of distance from the takeoff point.

For fixed-wing aircraft, most noise problems occur during takeoff or landing. It has therefore been necessary to define separate profiles for landing and for takeoff, and separate PNdB curves for the different power settings associated with landing and takeoff operations. Separate sets of takeoff and landing contours therefore result.

With helicopters, we are also concerned with takeoff and landing operations (as well as level flyover (cruise) flights, since helicopters often cruise at relatively low altitudes over populated areas). However, as a simplifying factor, one perceived noise level-vs-distance curve covers both takeoff and landing conditions. In further simplification, applicable to the extent to which generalized profiles fit flexible helicopter operations, a single altitude-vs-distance profile describes both takeoff and landing operations. Thus a single generalized contour can be used to depict noise levels produced during landings or takeoffs.

In a manner similar to that used in developing noise contours for flight operations, noise contours for ground runup or hover operations might be developed from a graph or table showing the variation of perceived noise level with angle at a constant distance about the aircraft and a graph showing the variations of perceived noise level with distance at different angles around the aircraft. Study of the noise characteristics of helicopters shows that the variation in perceived noise level with angle around a hovering helicopter (in and out of ground effect) is not consistent from aircraft to aircraft. For planning purposes, one may therefore assume a circular (i.e., equal noise in all directions) pattern with noise levels based

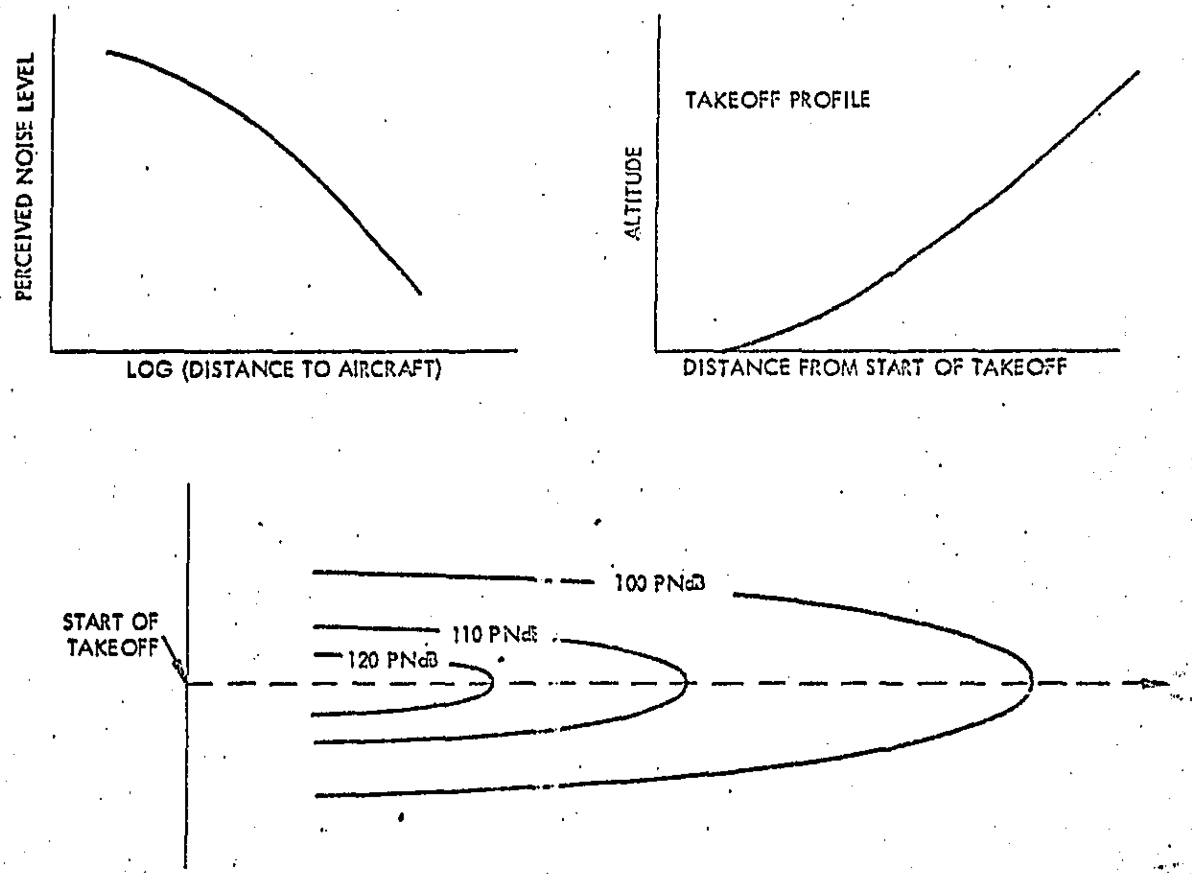


FIGURE 5. STEPS IN DEVELOPING PERCEIVED NOISE LEVEL CONTOURS FOR AN AIRCRAFT TAKEOFF

on the maximum expected at a constant distance about the aircraft. These maximum levels may be estimated from Fig. 2 and Fig. 3, as previously explained. Thus, no special ground runup contours are needed for estimating helicopter noise levels during hover.*

D. Generalized Noise Contours for Helicopters

Helicopters possess very flexible landing and takeoff profiles. Hence, "typical" profiles may be altered considerably to fit specific terrain features near a heliport. However, certain flight regimes are usually avoided for safety reasons and other possible flight procedures may be uneconomic or time consuming.

Recognizing that a considerable variation of flight profiles may be adopted to meet special localized conditions, a generalized takeoff (or landing) profile well within the capabilities of most current helicopters is shown in Curve A of Fig. 6. This contour is based upon a 5-to-1 slope beginning after a 50-foot ground roll.**

A generalized set of perceived noise level contours based upon this flight profile and applicable for either takeoffs or landings is shown in Fig. 7. The noise levels shown are for large turbine-powered helicopters. Corrections for other classes of helicopters are given in the figure.

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* Such simplifications are not possible for fixed-wing jet aircraft. For these aircraft, there are large differences in noise levels about the aircraft resulting from the noise characteristics of turbojet and turbofan engines.

** This flight profile also fits well within the suggested 8-to-1 slope for obstruction clearance surfaces beneath takeoff and landing paths, recommended for heliport design in Reference 4.

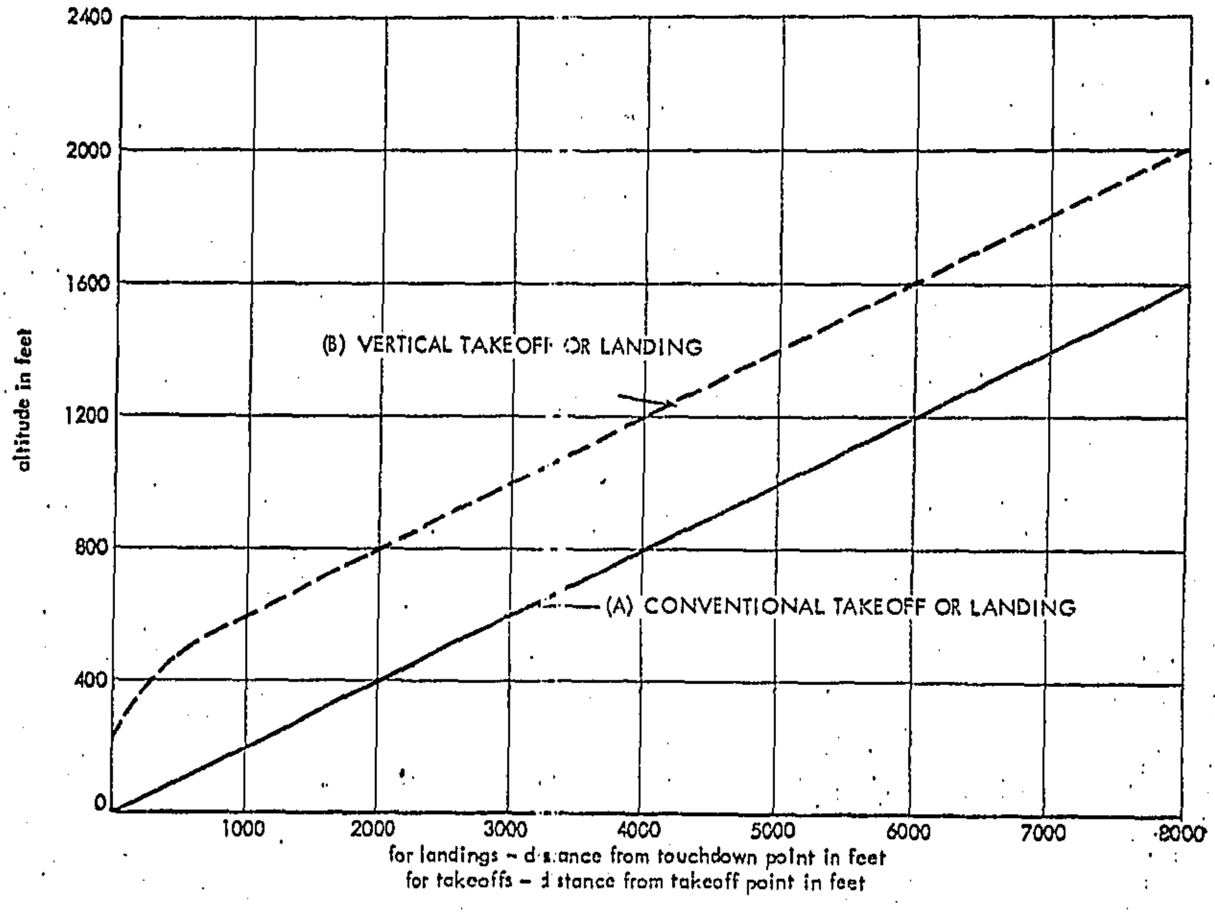
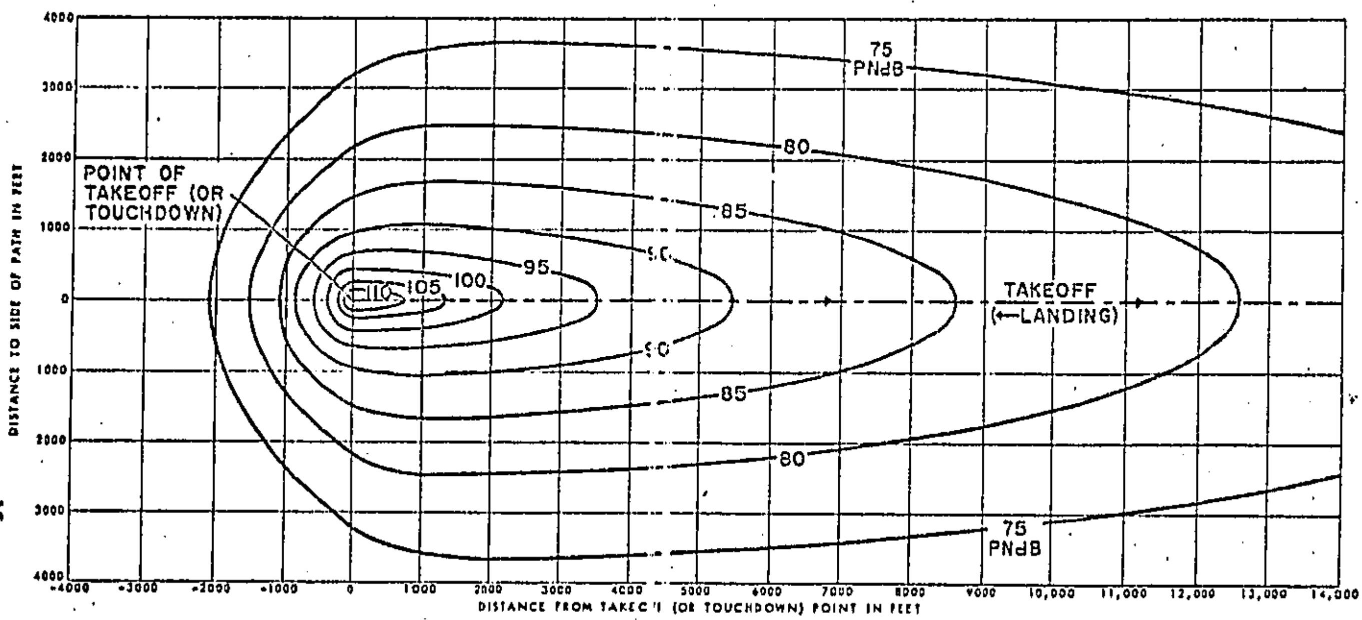


FIGURE 6. TAKEOFF AND LANDING PROFILES FOR HELICOPTER NOISE CONTOURS



CONTOUR CORRECTION CHART

HELICOPTER CLASSIFICATION		CORRECTIONS TO CONTOUR
NORMAL GROSS WEIGHT	ENGINE NO. AND TYPE	
10,000 LBS OR GREATER	ONE OR TWO PISTON	+ 5 PNdB
	ONE OR TWO TURBINE	0
LESS THAN 10,000 LBS	SINGLE PISTON	- 5 PNdB
	SINGLE TURBINE	- 10 PNdB

FIGURE 7. PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS AND LANDINGS OF CIVIL AND MILITARY HELICOPTERS (NON-VERTICAL TAKEOFF OR LANDING)

E. Vertical Takeoffs or Landings

Single-engine helicopters will generally avoid true vertical takeoffs or landings because of safety considerations. However for multi-engine helicopters, certificated under FAA category "A" helicopter ratings,* vertical takeoffs and landings are practicable and safe.[5] An example of the noise contours produced by such operations by multi-engine helicopters is shown in Fig. 8. The contours are based upon the flight profile shown by Curve B of Fig. 6. This profile shows a vertical ascent to 200 ft, with a transition above 200-ft altitude to a 5-to-1 takeoff slope.

Differences in noise levels produced by vertical compared to conventional takeoffs are further illustrated in Fig. 9. This figure shows noise levels resulting from helicopter takeoffs following the flight profiles given by Curves A and B of Fig. 6. Perceived noise levels are shown for positions on the ground along a line parallel to the flight path but displaced 200 ft to one side. The vertical takeoff results in lower noise levels over much of the flight path beyond the immediate vicinity of the takeoff point. However, the difference between noise levels becomes quite small at large distances from the takeoff point.

F. Applications of Contours

When studying the noise environment at a specific heliport, one may often wish to draw detailed noise contours applicable for that heliport. One complication that may arise in using the generalized noise contours of Fig. 7 is that the takeoff or departure path may often be curved. For a straight takeoff or departure, Fig. 7 may be used directly. However, if the flight path is curved, the contours must be modified to conform to the curved flight path. If the flight profile approximates that of Fig. 7, the contours need only be "bent" or curved so that the center line coincides with the actual

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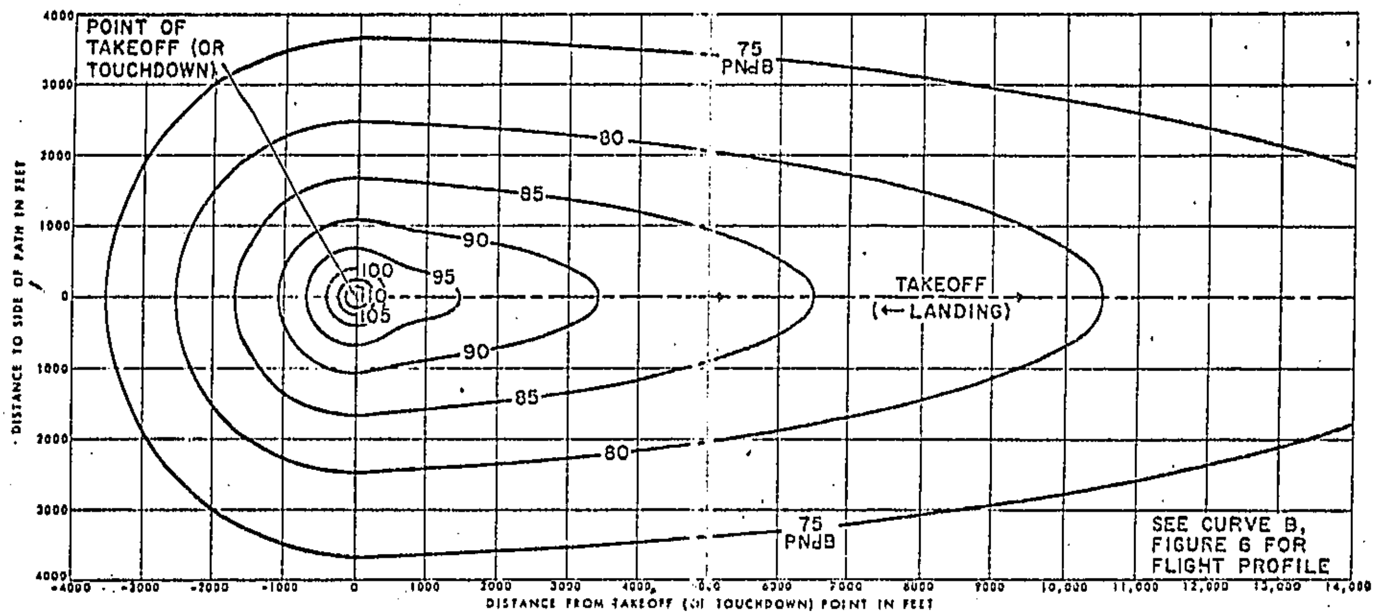
* FAA category "A" helicopter ratings requires full transport aircraft single-engine climb capability and takeoff procedures based upon continuation of flight upon loss of engine at the most critical point.



CONTOUR CORRECTION CHART

HELICOPTER CLASSIFICATION		CORRECTIONS TO CONTOUR
NORMAL GROSS WEIGHT	ENGINE NO. AND TYPE	
10,000 LBS OR GREATER	ONE OR TWO PISTON	+ 5 PNdB
	ONE OR TWO TURBINE	0
LESS THAN 10,000 LBS	SINGLE PISTON	- 5 PNdB
	SINGLE TURBINE	- 10 PNdB

FIGURE 8. PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS AND LANDINGS OF TYPICAL LARGE TWO-ENGINE TURBINE-POWERED HELICOPTER - VERTICAL LIFTOFF TO (DESCENT FROM) 200 FT. ALTITUDE

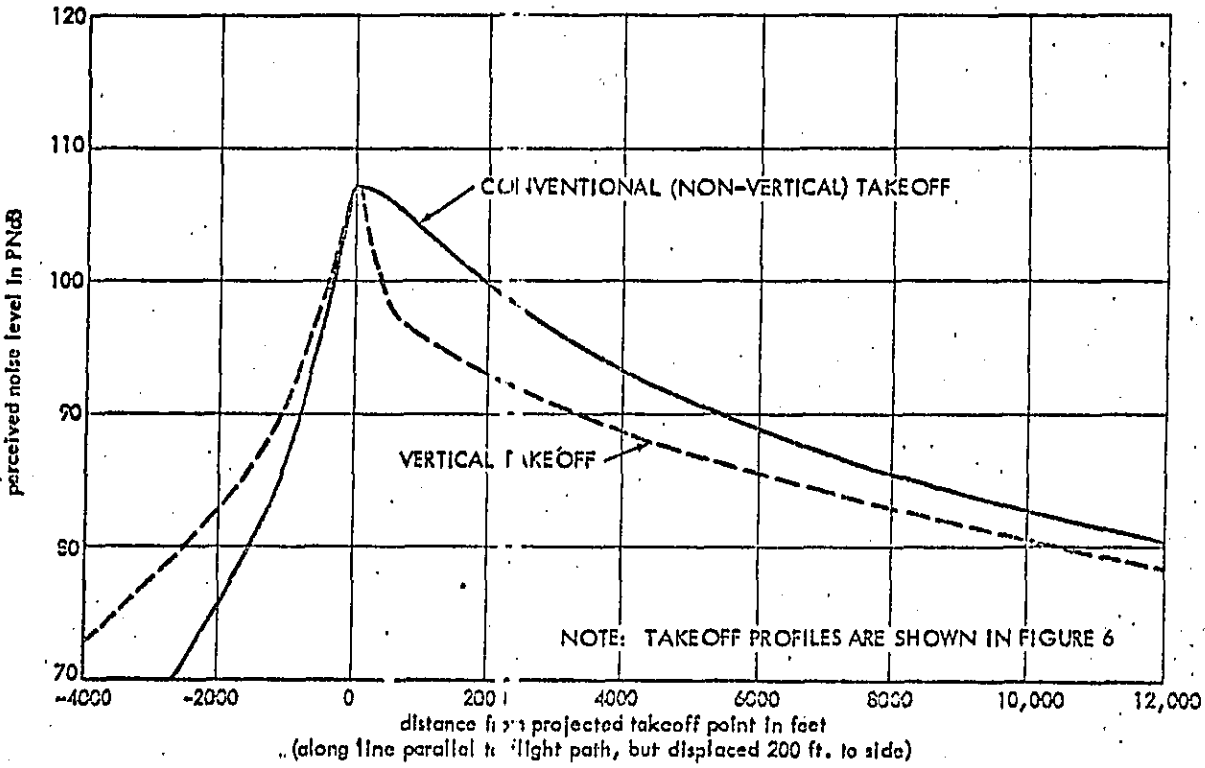


FIGURE 9. COMPARISON OF PERCEIVED NOISE LEVELS AT GROUND POSITIONS NEAR TAKEOFF PATH FOR CONVENTIONAL AND VERTICAL TAKEOFFS OF LARGE TURBINE-POWERED HELICOPTER

curved flight path. Figure 10 illustrates how contours are "bent" to conform to a curved flight path. In the figure we see that at corresponding distances along, and at perpendicular distances to the side of the flight path, the contour values are the same for a straight-out path and a curved path. For example, at point A', 3600 ft from the takeoff point on the curved flight path, the perceived noise level is the same as at point A on the straight-out path, which is also at 3600 ft. Similarly, the perceived noise level at point C, 2000 ft out and 600 ft to the side of the straightout flight path is the same as at point C', 2000 ft out along the curved flight path and 600 ft to the side of, and perpendicular to, the flight path. Other points on the curved noise contours can be located in a similar manner.

Another complication that may arise is the occurrence of a takeoff or landing profile much different than that assumed in developing the generalized profiles. New profiles can be generated, of course, using the procedures already discussed. However, if the desired flight profile approximates a constant slope, the generalized profiles of Fig. 7 may be adapted quite easily. In Fig. 7 noise levels at distances perpendicular to the flight path are denoted at 1000-foot intervals along the flight path. The contours may be foreshortened or lengthened, corresponding to steeper or more gradual flight profiles by plotting the perceived noise level values along lines perpendicular to the flight path but spaced at other than 1000-foot intervals. For example, if noise contours for a 3-to-1 takeoff slope are needed, lines perpendicular to the flight path can be plotted at (3/5 x 1000) or 600-foot intervals instead. Repeating this procedure for consecutive 600-foot intervals will result in a translation of the contours of Fig. 7 into contours for a takeoff path having a 3-to-1 slope.

Following this procedure, for example, point A on the straight-out flight path in Fig. 10, 3600 ft from the takeoff point, would be plotted as point A", (3/5 x 3600) or 2160 feet from the takeoff point, for a modified 3-to-1 takeoff profile. Similarily, point C" on the modified takeoff profile would be plotted 1200 ft from the takeoff point and 600 ft to the side of the flight path.

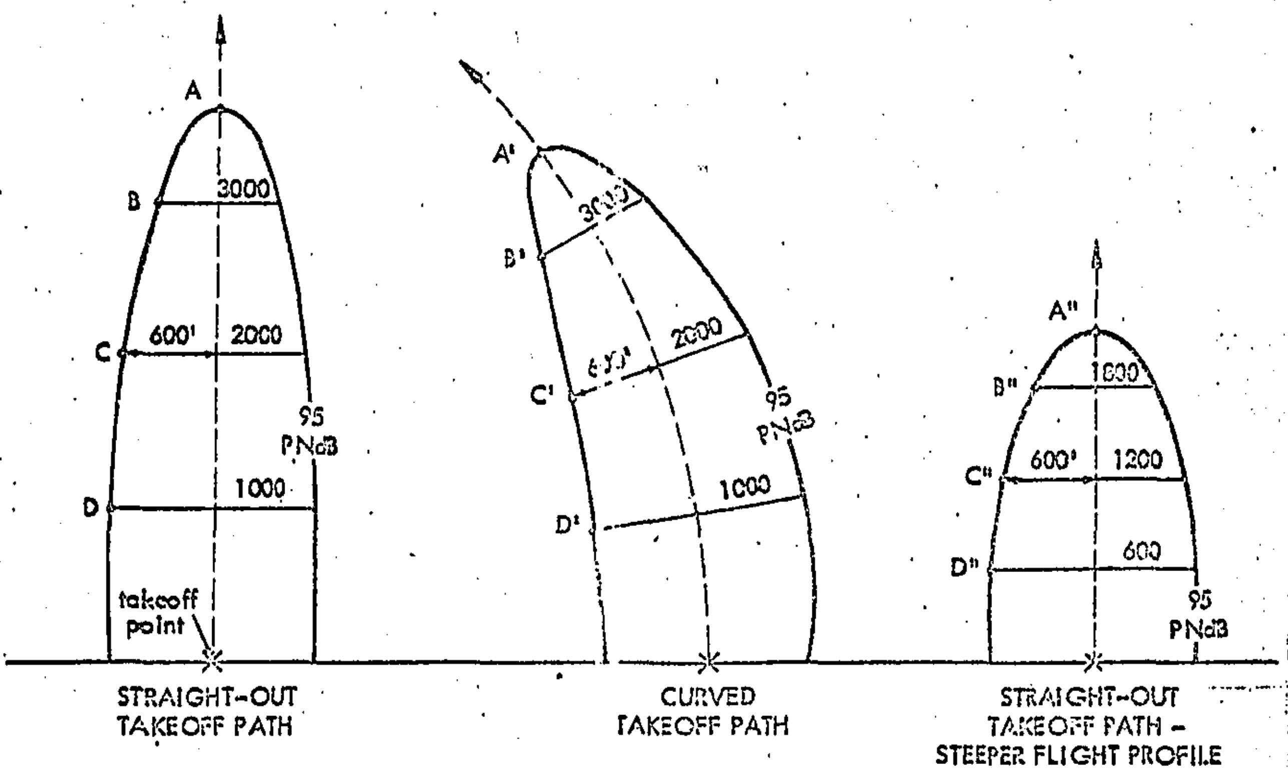


FIGURE 10. ILLUSTRATION OF ADAPTION OF PERCEIVED NOISE LEVEL CONTOURS TO CURVED FLIGHT PATH OR CHANGE IN FLIGHT PROFILE

III. DETAILED DESCRIPTION OF THE PROCEDURE

The procedures for determining helicopter noise compatibility with varied land uses are described in this section step by step in the order shown in Fig. 1. To demonstrate the application of each step in the procedure, a running illustration is inserted in the text.

Step 1 - Obtain Data on Helicopter Operations

The previous section of the report has described how noise contours and other presentations of noise level information are used to estimate the perceived noise levels resulting from helicopter operations. Before this information can be applied, it is first necessary to define the helicopter operations. Flight paths and flight profiles must be established. Then the number of operations (takeoffs, landings, flyovers) expected for each class of helicopters must be determined. This activity information should be gathered for both daytime (0700-2200) and nighttime (2200-0700) periods. Table I lists some of the current civil and military helicopters in each of the four helicopter classes.

Since helicopter flight paths may show considerable variation, care should be used in establishing paths which are reasonable averages of the expected actual paths. In some cases one may wish to consider a number of flight paths, and later determine the noise levels resulting from each flight path.

For ground runup or hover operations, the type of helicopter, location of the operation and nature of operation should be determined. The number of operations and duration expected in both daytime and nighttime periods should be established.

In planning, one is generally concerned with operations expected in the future. Predictions and trends should be established with care. One must be alert to possibilities other than straightforward extrapolations of current flight activities. One should consider such questions as: what are the possibilities of use by larger helicopters; what is the possibility of nighttime as well as daytime operations; are different landing and departure flight paths likely as the number of heliports in the vicinity is increased; what effect are changes in land use in the

TABLE I

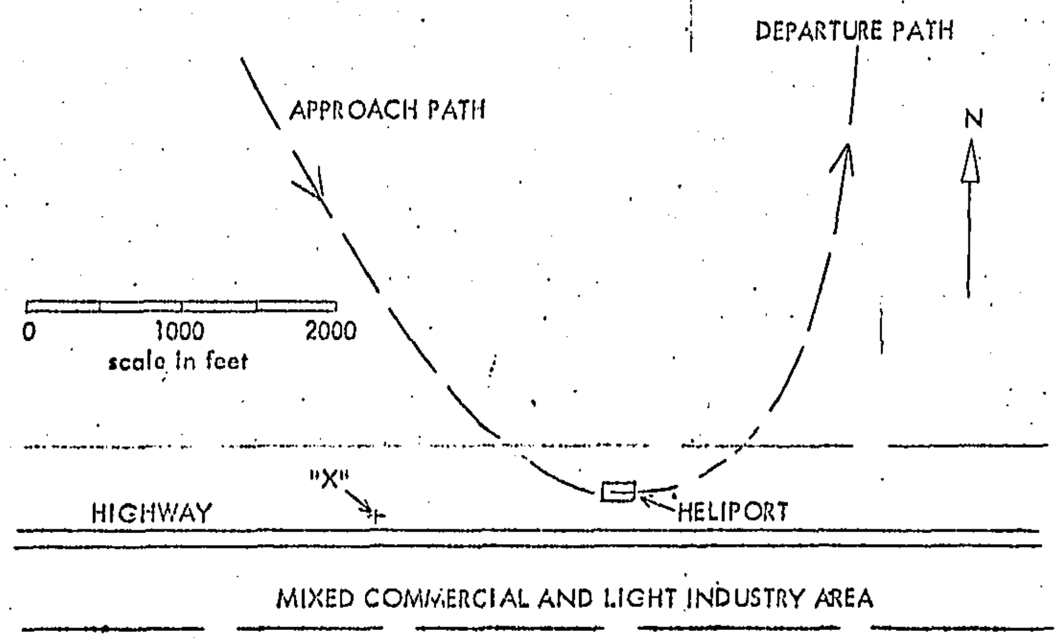
CLASSIFICATION OF REPRESENTATIVE TYPES OF CIVIL AND MILITARY HELICOPTERS

HELICOPTER CLASSIFICATION*		REPRESENTATIVE TYPES	
Normal Gross Weight	Engine Type	Civil	Military
10,000 lbs or greater	one or two piston	Sikorsky S-58, Vertol 44	CH-21, CH-34, CH-37
	one or two turbines	Sikorsky S-61, Vertol 107-2	UH-2A, CH-3, CH-53, CH-54, CH-46, CH-47
Less than 10,000 lbs	single piston	Bell 47G, 47J, Brantly B2, Hiller E4, 12E, Hughes 269A, Sikorsky S-55	CH-19, CH-13, OH-23
	single turbine	Bell 204B, Hiller 1100, Hughes 369, Sikorsky S-62A	HH-52A, UH-1, OH-5, OH-4, HH-43B

* Classification of Fig. 2 for estimating noise levels.

vicinity of the heliport likely to have on volume of traffic and selection of flight paths; etc.

As an example, consider a heliport located in a mixed commercial and light industrial area, as shown in the sketch below.



Step 1 consists of determining the following information by observation and discussion with the heliport and helicopter operators:

1) flight paths are established as shown in the sketch. Approaches follow an approximate 5-to-1

slope. Takeoffs follow an approximate 3-to-1 slope because of some terrain obstacles lying to the northeast.

2) the heliport will be used by both large turbine-powered transport helicopters and smaller turbine- and piston-powered business helicopters. Twelve daytime flights are expected for the transport operations and up to 25 flights per day (25 takeoffs and 25 landings) are expected for the business aircraft. Two-thirds of the business aircraft are expected to be piston-powered, the remaining one-third, turbine-powered. Few nighttime operations are anticipated and no extended runup operations are planned.

Step 2 - Determine Perceived Noise Levels for Helicopter Operations

With definition of the flight paths and hover positions accomplished in Step 1, the noise exposure for the land areas of interest may be established using the noise information of Section II. Depending on the extent of one's interest, complete perceived noise level contours may be established or perhaps only the noise levels at one or two particular locations need be determined.

For positions directly under the flight path, perceived noise levels may be determined directly from Fig. 2. Figure 2 with Fig. 3 permit estimation of noise levels at any horizontal distance for a helicopter operating on or very near the ground. For positions to the side of a flight path, Fig. 4 may be used in conjunction with Fig. 2 to determine the perceived noise level. For many takeoff and landing operations, the generalized noise contours of Fig. 7 can be used. These contours may be modified for curved paths or for paths of different profiles as discussed in the later portion of Section II.

Continuing our example, suppose we are concerned with estimating the perceived noise levels at Point "x" shown in the sketch on page 23. We also will later wish to develop a complete set of noise contours for the area surrounding the heliport.

To determine the noise levels at Point "x" we measure the distance from Point "x" to the nearest flight path. This distance scales 900 ft from the approach path, at a point approximately 1000 ft before the touchdown point. Reference to the flight profile Curve A of Fig. 6 shows that the expected altitude at a point 1000 ft before touchdown is approximately 190 ft. Entering Fig. 4 with this altitude and horizontal distance information (190 and 900 ft) we obtain a slant distance of 920 ft. From Fig. 2 we estimate noise levels of 92 PNdB for the large turbine-powered helicopters, 87 PNdB for the smaller piston-powered helicopters and 82 PNdB for the smaller turbine-powered helicopters.

To develop the noise contours we use the generalized contours of Fig. 7, applying the procedures outlined in Section II for adjusting the contours for curvature of flight path and for a change in the slope of the takeoff flight path. Results of this procedure are shown in Fig. 11.

Step 3 - Determine Composite Noise Ratings for Helicopter Operations

The Composite Noise Rating (CNR) for the different helicopter noises are obtained by adding to the perceived noise levels corrections for those operational factors that most influence reactions to aircraft noise. The most pertinent corrections for helicopter operations are for frequency of operation and for the relative utilization of flight paths. Correction numbers for these factors are given in Table II. For runup or hover operations, the operational factor considered most important is the average hourly running time. The correction applied to the perceived noise levels for this factor is given in Table III.

The correction for time of day given in Table IV is needed when considering land use activities likely to be affected

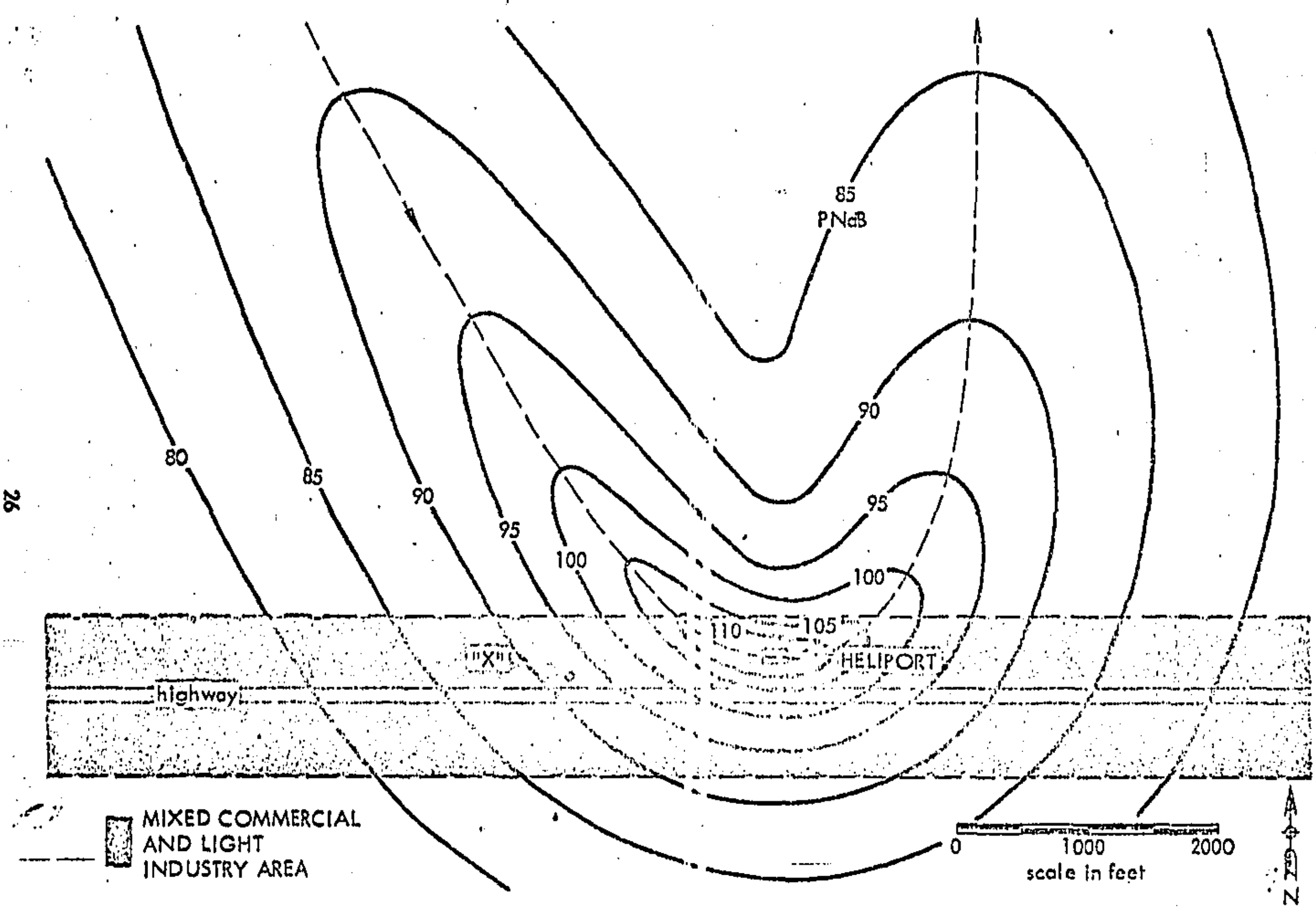


FIGURE 11. PERCEIVED NOISE LEVELS IN VICINITY OF HELIPORT (EXAMPLE)

TABLE II

CORRECTIONS FOR NUMBER OF FLIGHT OPERATIONS
(TAKEOFFS OR LANDINGS) AND FLIGHT PATH UTILIZATION

Total Activity	
Number Per Hour	Correction*
20 or greater	+15
7 - 19	+10
2 - 6.9	+ 5
0.7 - 1.9	0
0.2 - 0.69	- 5
less than 0.2	-10
Flight Path Utilization	
Utilization	Correction*
30% - 100%	0
10% - 29%	- 5
3% - 9%	-10
less than 3%	-15

TABLE III

CORRECTION FOR DURATION OF GROUND
RUNUPS OR HOVER OPERATIONS

Duration in Minutes Per Hour	Correction*
2 or greater	+ 5
0.7 - 1.9	0
0.2 - 0.69	- 5
0.07 - 0.19	-10
less than 0.007	-15

TABLE IV

CORRECTION FOR TIME OF DAY

Time of Day**	Correction*
0700 - 2200	0
2200 - 0700	+10

* To be added to the perceived noise level.

** In general, the ratio of daytime-to-nighttime operations is such that daytime operations will determine the Composite Noise Rating. Only when nighttime activity is disproportionately high will the nighttime correction affect the Composite Noise Rating.

by helicopter operation at nighttime. For example, if one is interested in evaluating the effects of helicopter noise on commercial land uses, one would normally consider only daytime operations since the commercial activities are generally drastically curtailed during nighttime. However, when considering residential land use, one would certainly include consideration of nighttime activities.

A CNR is computed for each of the four classes of helicopters. And whenever applicable, separate CNRs would be computed for both daytime and nighttime operations. Then, from the comparable daytime and nighttime CNRs, the highest CNR, representing the most severe noise exposure in terms of expected impact on land use, would be selected.

At this point in the analysis, a CNR will result for each takeoff and landing operation for each class of helicopters. Similarly, a CNR will result for each runup or hover operation for each class of helicopters. From the various CNRs one must be chosen to apply to the area in question for all flight operations, and another CNR to apply for all runup operations. Since the operations have been divided into various categories and since the noise perceived in any one location will frequently be due to operations on several flight paths, CNRs of comparable value must be recombined. Only Composite Noise Ratings within 3 units of the maximum CNR need be considered. If there are three or more CNR values fulfilling this requirement, 5 units should be added to the highest CNR to determine the applicable CNR for that operation. If there are less than three, the highest CNR applies.

> We can now determine the Composite Noise Rating at Point "x" in Figure 11. The analysis for each of the three classes of helicopters involved is summarized on Work Sheet No. 1. In accordance with the rule on summation, the combined CNR rating for Point "x" is 92.

<u>Step 4 - Check Importance of Other Noise Sources</u>

With helicopter noise now defined in terms of both perceived noise levels and Composite Noise Ratings, one can now check the relative importance of helicopter noise compared to other

WORK SHEET NO. 1

Helicopter Class	No. of Oper. Per Hour	Flight Path Util.	PNdB	CNR CORRECTIONS			CNR
				No. of Oper.	Flt. Path Util.	Time	
large turbine	0.8	100%	92	0	0	0	92
small piston	1.1	100%	87	0	0	0	87
small turbine	0.6	100%	82	-5	0	0	77

intermittent or continuous sources of noise. Information concerning the noise produced by other sources may be gathered from measurement, inspection or estimation from accumulated engineering data. Some helpful noise level information is presented in Figs. 12 through 15.

Figure 12 compares helicopter noise with the noise produced by some operations of fixed-wing aircraft.* The upper shaded area shows takeoff noise levels produced by current four engine turbojet and turbofan aircraft. The next shaded area shows noise levels produced by takeoff of two engine piston-powered commercial transport such as the DC-3, Convair 340 and Martin 404. The lower shaded band shows the noise produced during cruise flight of smaller two engine piston aircraft such as the Aero Commander, Beech 18 Series, Cessna 310 Series, Piper Apache and Aztec, etc. Also shown on the figure are the perceived noise levels for large piston-powered helicopters, large turbine-powered helicopters

* More detailed noise information is provided in References 1 and 6.

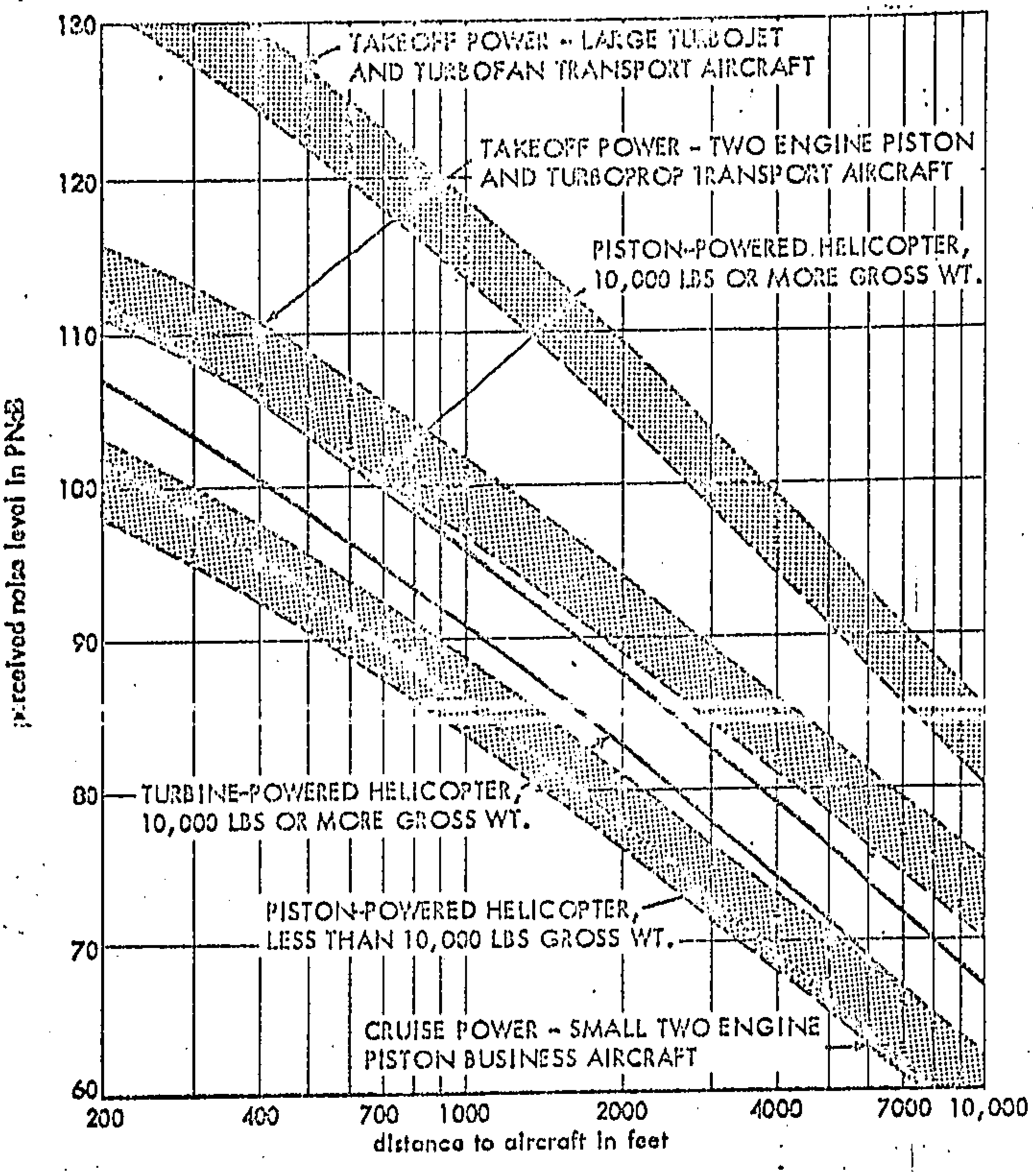


FIGURE 12. COMPARISON OF HELICOPTER NOISE WITH OTHER TYPICAL AIRCRAFT NOISE

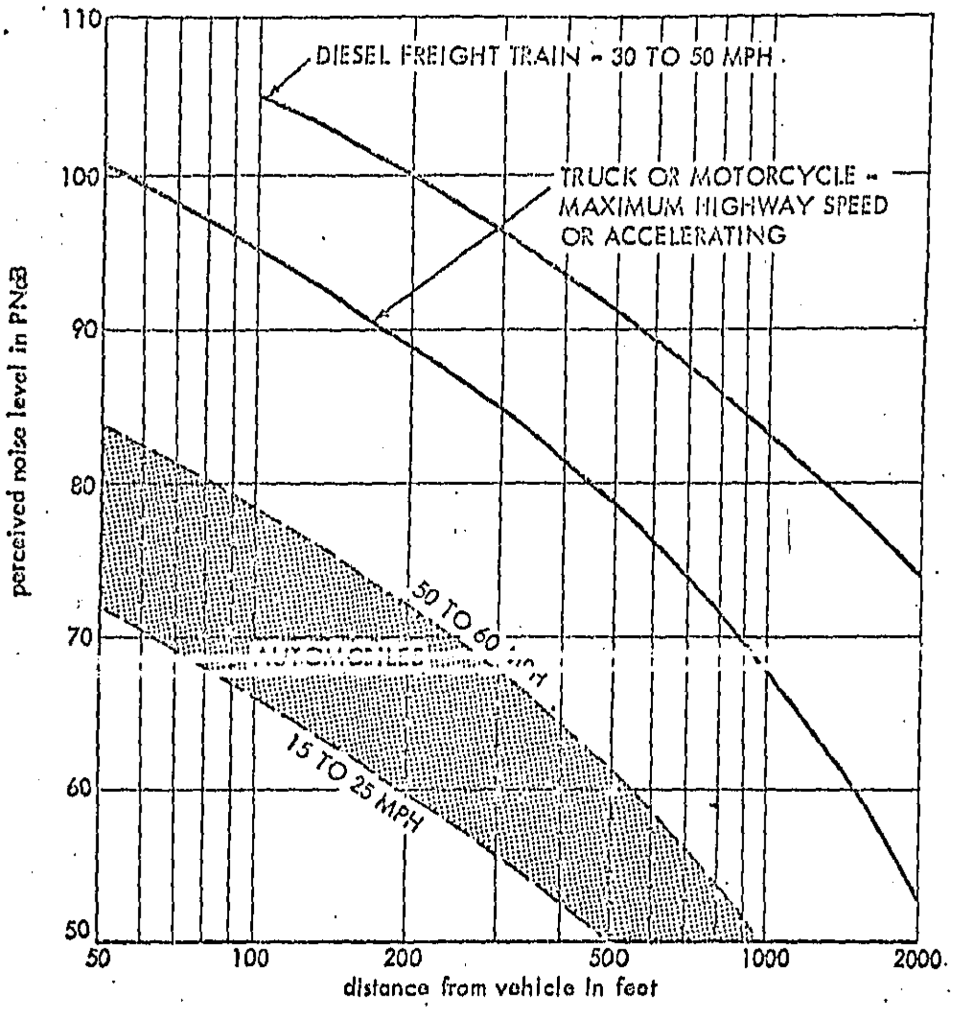


FIGURE 13. TYPICAL INTERMITTENT NOISE PRODUCED BY SURFACE TRANSPORTATION VEHICLES

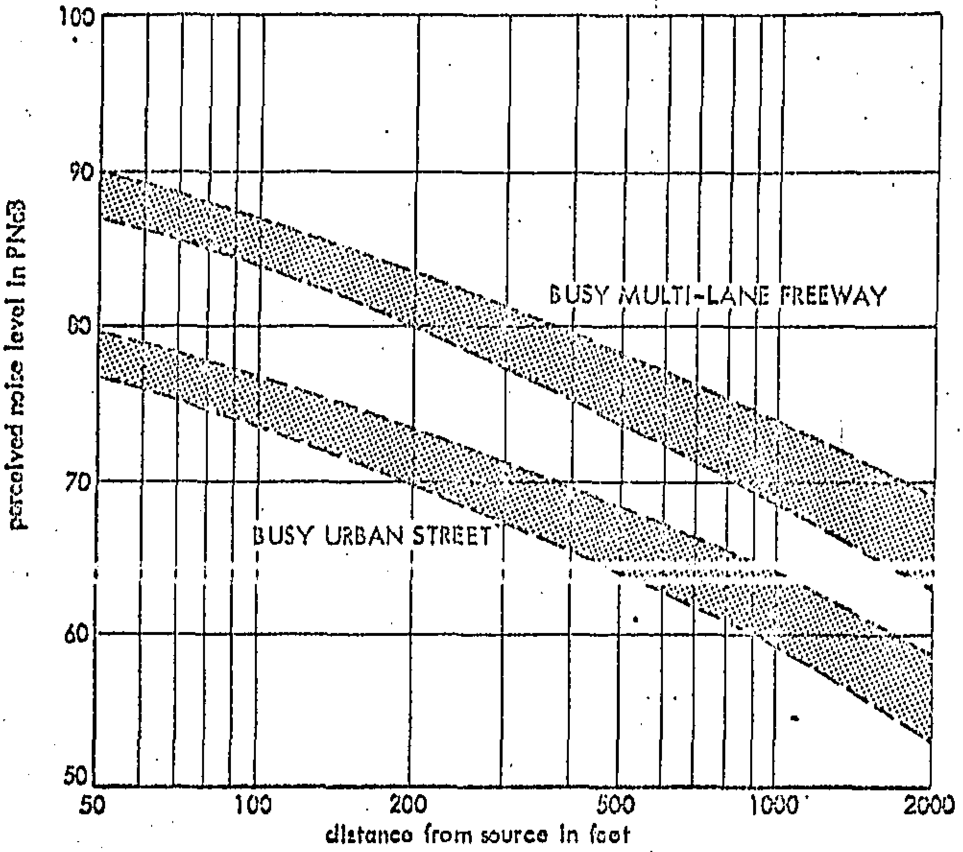


FIGURE 14. TYPICAL CONTINUOUS NOISE PRODUCED BY HEAVY SURFACE TRAFFIC

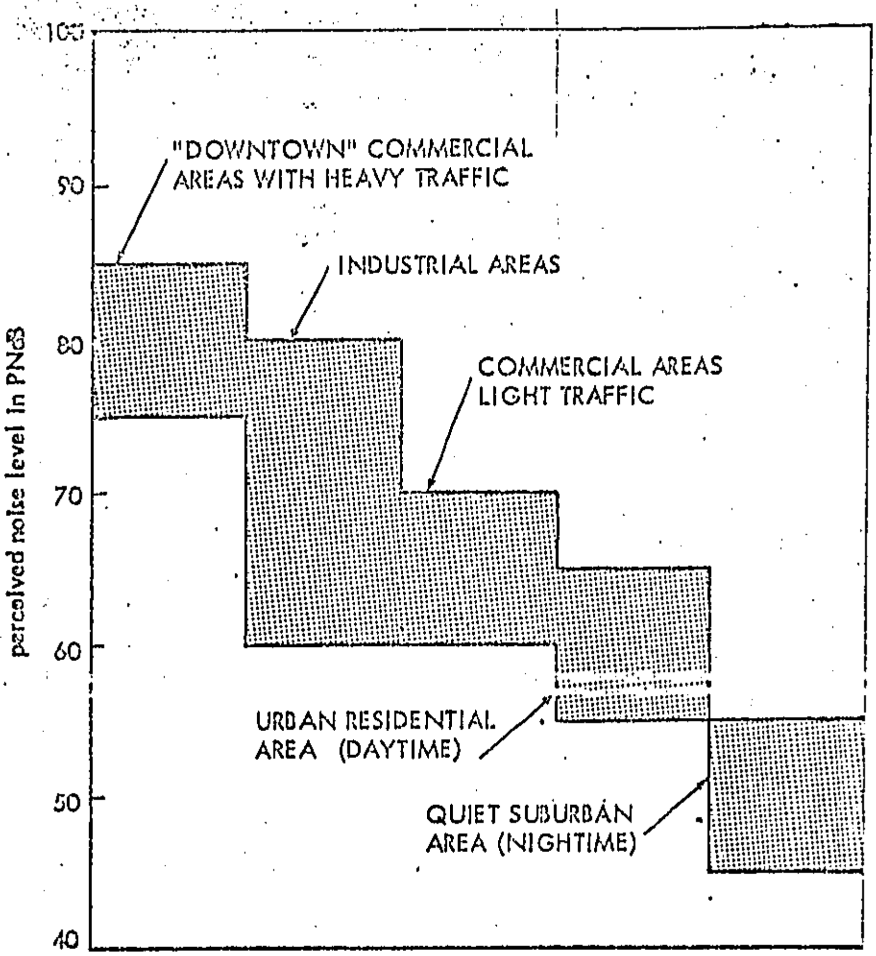


FIGURE 15. TYPICAL CONTINUOUS BACKGROUND NOISE LEVELS

and the small single engine piston-powered helicopters, reprinted from Fig. 2. It is clearly apparent from the table that the noise levels produced by helicopter operations are relatively moderate compared to those resulting from many fixed-wing aircraft operations.

Figure 13 shows some typical noise levels produced by various types of surface transportation vehicles --- automobiles, trucks, motorcycles and trains. Figure 14 shows the near-continuous noise produced by heavy surface traffic produced on a multi-lane freeway and a busy urban street. Figure 15 presents estimates of the ambient noise levels expected in various urban and suburban situations.

To illustrate the application of some of the noise information, Fig. 16 shows a comparison of helicopter noise with freeway noise. In this figure we have assumed that a proposed helicopter route is aligned with the center line of a heavily travelled, multi-lane freeway. The figure shows the resulting noise levels anticipated for operation of a two-engine turbine transport helicopter at altitudes of 500, 1000 and 2000 ft directly above the freeway. At distances close to the freeway the benefit from flying at the higher altitudes is quite pronounced. However at distances beyond about 2500 ft, there is little variation in helicopter noise for flights at the different altitudes. One may also note from the figure that at the 2000 foot altitude, the helicopter noise never intrudes more than 10 dB above the freeway noise, while at 500 ft altitude, the helicopter noise levels exceed the freeway noise by more than 10 dB over a considerable range of distances.

To determine whether or not helicopter noise is the dominant noise source we may now compare the levels produced by other noise sources using the decision guide given in Table V. To use this table we must first determine, for other intermittent noise sources, a Composite Noise Rating by application of the correction values given in Table VI.

Point "x" is located in the midst of the mixed industrial and commercial area. This area is subject to moderate traffic noise from the main through street.

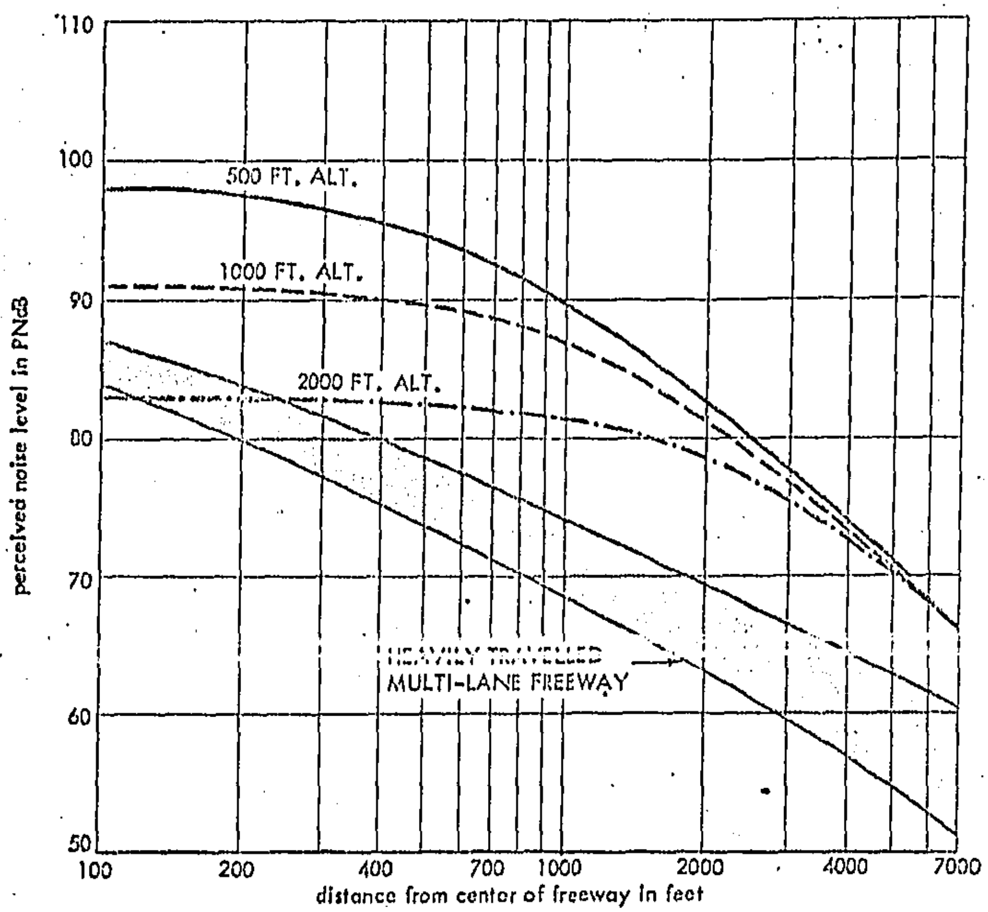


FIGURE 16. COMPARISON OF HELICOPTER NOISE WITH FREEWAY NOISE (LARGE TWO ENGINE TURBINE HELICOPTER FLYING ABOVE CENTERLINE OF FREEWAY)

TABLE V

DECISION GUIDE FOR COMPARING HELICOPTER NOISE WITH OTHER NOISE SOURCES

Sources	Perceived Noise Level PNdB	Composite Noise Rating
Helicopter noise	A	a
Other intermittent noise (other aircraft, surface vehicles)	B	b
Continuous noise (traffic, industry)	C	-

Comparison	Helicopter Noise Implications
$a \leq b$	May be noticeable, but should be of no concern.
$a \geq b + 5$	Dominant intermittent noise source; compare to continuous noise.
$a \leq c$	May be noticeable, but should be of no concern.
$a \geq c + 5$	Noticeable; use Table VII.

TABLE VI

CORRECTION FOR NUMBER OF OCCURRENCES OF INTERMITTENT NOISE (OTHER THAN AIRCRAFT NOISE)

Number Per Hour	Correction*
20 or greater	+15
7 - 19	+10
2 - 6.9	+ 5
0.7 - 1.9	0
0.2 - 0.69	- 5
less than 0.2	-10

* To be added to the perceived noise level.

From Fig. 15, continuous noise levels are estimated to be approximately 65 PNdB. From Fig. 13, intermittent noise peaks from automobiles travelling on the nearby through street are estimated to reach 75 PNdB. Assuming a frequency of automobile traffic of approximately 150 vehicles per hour, the CNR for the automobile traffic is 75 + 15, or 90. Comparison of these values with the CNR previously determined for the helicopter operations (using the decision guide of Table V) shows that helicopter noise is the dominant noise source. Hence, the addition of helicopter noise may change the noise environment at Point "x" appreciably.

Step 5 - Determine General Land Use Compatibility With Helicopter Noise

If, on the basis of the previous step, helicopter noise is the dominant source, we can now evaluate the impact of the helicopter noise on various land uses. This rating is done by comparing the CNR values for helicopter noise with those given in Table VII. Four Noise Sensitivity Zones (Zones I, II, III and IV) with accompanying sets of CNR ratings (one

TABLE VII

LAND USE COMPATIBILITY CHART FOR HELICOPTER NOISE

Noise Sensitivity Zone	Composite Noise Rating (CNR)		LAND USE COMPATIBILITY								
	Takeoffs and Landings	Ground Runups	Residential	Commercial	Hotel, Motel	Offices, Public Buildings	Schools, Hospitals, Churches	Theaters, Auditoriums	Outdoor Amphi-Theaters, Theaters	Outdoor Recrea-tional (Non-spectator)	Industrial
I	Less Than 90	Less Than 70	yes	yes	yes	yes	yes	Note (A)	Note (A)	yes	yes
II	90-100	70-80	yes	yes	yes	yes	Note (C)	Note (C)	no	yes	yes
III	100-115	80-95	Note (B)	yes	Note (C)	Note (C)	no	no	no	yes	yes
IV	Greater Than 115	Greater Than 95	no	Note (C)	no	no	no	no	no	yes	Note (C)

NOTE (A) - Possible interference for indoor or outdoor music auditoriums and outdoor theaters. Make more detailed noise studies.

NOTE (B) - Case history experience indicates that individuals in private residences may complain, perhaps vigorously. Concerted group action is possible.

NOTE (C) - Potentially serious interference, with likelihood of serious adverse reactions from individuals and groups affected.

set for helicopter noise, and one set for ground runup noise) are shown in Table VII. The following nine columns in the table show the compatibility of land usage for a number of land use categories having different sensitivities to helicopter noise.

For most columns the ratings start, for the lowest noise compatibility zone, with the word "yes" indicating that there should be no adverse effects from the helicopter noise. Corresponding to the higher noise sensitivities some of the columns have the word "no" printed. "No" indicates that helicopter noise will likely interfere seriously with the land use.* Between the "yes" and "no" response there is a range of CNR ratings over which there is increasing probability of interference or annoyance from the helicopter noise.

Table VII is based upon consideration of the typical range of human activities and work tasks involved in the different land use categories. In developing the table, major consideration has been given to the effects of noise in:

a) generating feelings and expressions of annoyance and dissatisfaction; and

b) interfering with speech communication.

The table is based upon comparisons of the noise exposure and complaint histories encountered in numerous aircraft noise problems at various military and civil airfields.1,2/ The table assumes that the type of lightweight building construction for the different land uses is that which would be normally used when aircraft noise (either fixed-wing or helicopter) is of no concern. Special noise control construction has not been considered in the tables.

These Noise Sensitivity Zones should, of course, be used as guides to compatible land use planning and to expected types of response, not as rigid geographic boundaries. Intelligent and careful interpretation is called for to

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* Reference 2 provides information as to steps that can be taken in the building design to increase its compatibility with aircraft noise.

WORK SHEET NO. 2

Helicopter Type	Operation	CNR Contour	Activity Correc.[1]	Utiliz. Correc.[2]	Time of Day Correc.[3]	Contour Chart	Contour Correc.	Noise Contour, PNdB
Large Turbine	Takeoff	100	0	0	0	Fig. 7*	0	100
Medium Single Engine Piston	Takeoff	100	0	0	0	Fig. 7*	-5	105
Medium Single Engine Turbine	Takeoff	100	-5	0	0	Fig. 7*	-10	115
Large Turbine	Landing	100	0	0	0	Fig. 7	0	100
Medium Single Engine Piston	Landing	100	0	0	0	Fig. 7	-5	105
Medium Single Engine Turbine	Landing	100	-5	0	0	Fig. 7	-10	115

1 Table II

2 Table III

3 Table IV

* Modified for 3 to 1 takeoff slope

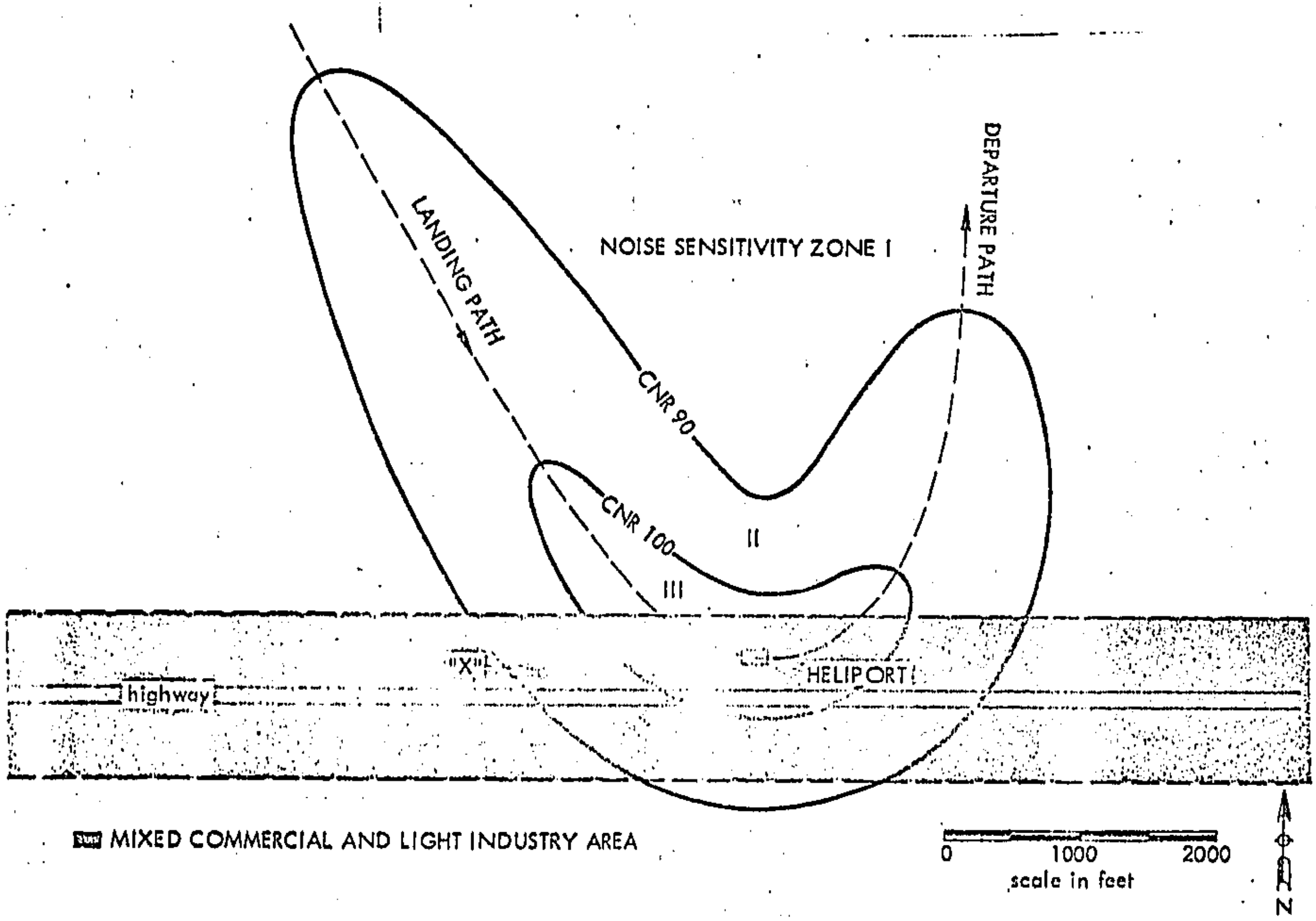

FIGURE 17. LAND USE NOISE SENSITIVITY ZONES IN VICINITY OF HELIPORT (EXAMPLE)

if this area is developed for private housing. Perhaps other, less noise sensitive uses for this land can be established; perhaps helicopter flight paths can be adjusted to reduce the noise intrusion.

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3. K. D. Kryter, K. S. Pearsons, "Some Effects of Spectral Content, Duration and Rise Time of Sound on Perceived Noise Level", J. Acoust. Soc. Am., 35, 866-883 (1963) - also see: K. D. Kryter, K. S. Pearsons, "Modification of Noy Tables", J. Acoust. Soc. Am., 36, 394-397 (1964).

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6. FAA Technical Report ADS-35, "Noise Contours for Short and Medium Range Transport Aircraft and Business Aircraft", March 1965 (prepared by BBN for the FAA under Contract No. FA64WA-4949).

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10. U. S. Army USAARU Report No. 64-1, "A Survey of Internal and External Noise Environments in U. S. Army Aircraft", (Dec. 1963).

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14. H. E. von Gierke, "Aircraft Noise Sources", Chap. 13, Handbook of Noise Control, McGraw-Hill Book Co., New York (1957).

15. U. S. Army TCREC Technical Report 62-73, "A Study of the Origin and Means of Reducing Helicopter Noise" (Nov. 1962).

16. P. A. Franken, L. L. Beranek, Chap. 13, "Noise Control in Transportation", Noise Reduction, McGraw-Hill Book Co., New York (1960).

APPENDIX A

This Appendix discusses the analysis procedures, sources of information and some of the detailed noise information from which the generalized helicopter noise charts and contours, presented in the body of the report, were derived. This study emphasized the collection and comparison of helicopter noise measurements obtained under a variety of operating conditions and from a variety of sources. The major aim of the study was to define the noise environment produced by helicopters (with noise environment interpreted in terms of subjective reactions as expressed in perceived noise levels)* rather than to determine individual sources of helicopter noise or to explore methods of controlling or reducing helicopter noise.

The major sources of noise information used in preparation of this report are:

a) noise measurements of military helicopters conducted for the U. S. Army where acoustical data were obtained during takeoff, landing, flyover and hover operations;9,10/

b) data supplied by the Federal Aviation Agency on the operations and acoustical characteristics of several large civil helicopters;11/

c) noise information provided by helicopter manufacturers;

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* The perceived noise level concept has been developed and validated primarily by evaluation of fixed-wing aircraft noise signals. We have assumed in this report that the perceived noise level also adequately rates the relative noisiness or annoyance of helicopter sounds. In view of the limited psychoacoustic evaluations of helicopter noises done to date,3,7/ there is some question as to the adequacy of the perceived noise level, as currently calculated, in accurately rating various helicopter noises. This question is under investigation by the FAA.8/.

d) noise measurements by Bolt Beranek and Newman Inc. (BBN) at civil and military air bases where accurate positional and acoustical data were obtained during routine helicopter operations but where detailed information concerning aircraft operating conditions (operating gross weight, throttle settings, airspeeds, etc.) was lacking. Some information was gathered from BBN files. Additional field measurements of civil transport helicopters (Sikorsky S-55, S-61 and S-62, and Vertol V-107-2) and some of the smaller piston helicopters (Bell 47G and 47J, Brantly B2A) were made specifically for this study.

e) noise measurements conducted by BBN, in cooperation with helicopter manufacturers, where extensive positional and acoustical data were obtained during controlled aircraft operations. In these tests, helicopter noise was measured during: hover (in and out of ground effect), level flight flyovers at a constant airspeed at altitudes from 50 to 400 ft, and during takeoffs and landings. Hover measurements were made at 30° to 45° intervals at a constant radius about the aircraft. For the level flight flyovers, takeoffs and landings, measurements were made at a position directly under the flight path and at a position well to one side of the flight path.

Noise information was gathered for most of the current civil and military helicopters (piston- and turbine-powered, single and dual rotors) that are in widespread use. However, equally complete and comparable sets of measurements were not obtainable for each type of aircraft, and the collected noise data cannot be considered as exhaustively complete.

Perceived noise levels were calculated from the collected octave band noise data. When several sets of noise measurements were obtained for the same flight condition for a specific aircraft, the octave band noise spectra were adjusted to a common distance and a median noise spectrum established before calculating the perceived noise level. Curves showing the variation in perceived noise level with distance were generated by calculating octave band spectra at other than the measured distances, using inverse square corrections and standard SAE air attenuation values.12/ Perceived noise levels were then calculated from the derived octave band spectra.

The perceived noise level data were analyzed to establish the variations in perceived noise level:

a) with type of operation (takeoff, landing, flyover, and hover)

b) with distance

c) with size and type of helicopter

d) in a horizontal plane about the helicopter during hover conditions, and

e) in a vertical plane perpendicular to the flight path during flight operations.

A. Variation of Perceived Noise Levels With Type of Operation

Figure A-1 shows perceived noise levels at a distance of 250 ft for a number of helicopters plotted as a function of the aircraft normal gross weight. Various shaped symbols depict noise levels for takeoff, landing, level flight flyovers, and hover (in ground effect) conditions.* Piston- and turbine-powered aircraft are identified, as are single and dual rotor helicopters.

From the figure it is evident that the spread in perceived noise levels with flight conditions is generally quite small. For example:

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* The hover values in Fig. A-1 are generally the maximum observed in a horizontal radius about the aircraft. Average hover levels would generally be several PNdB lower.

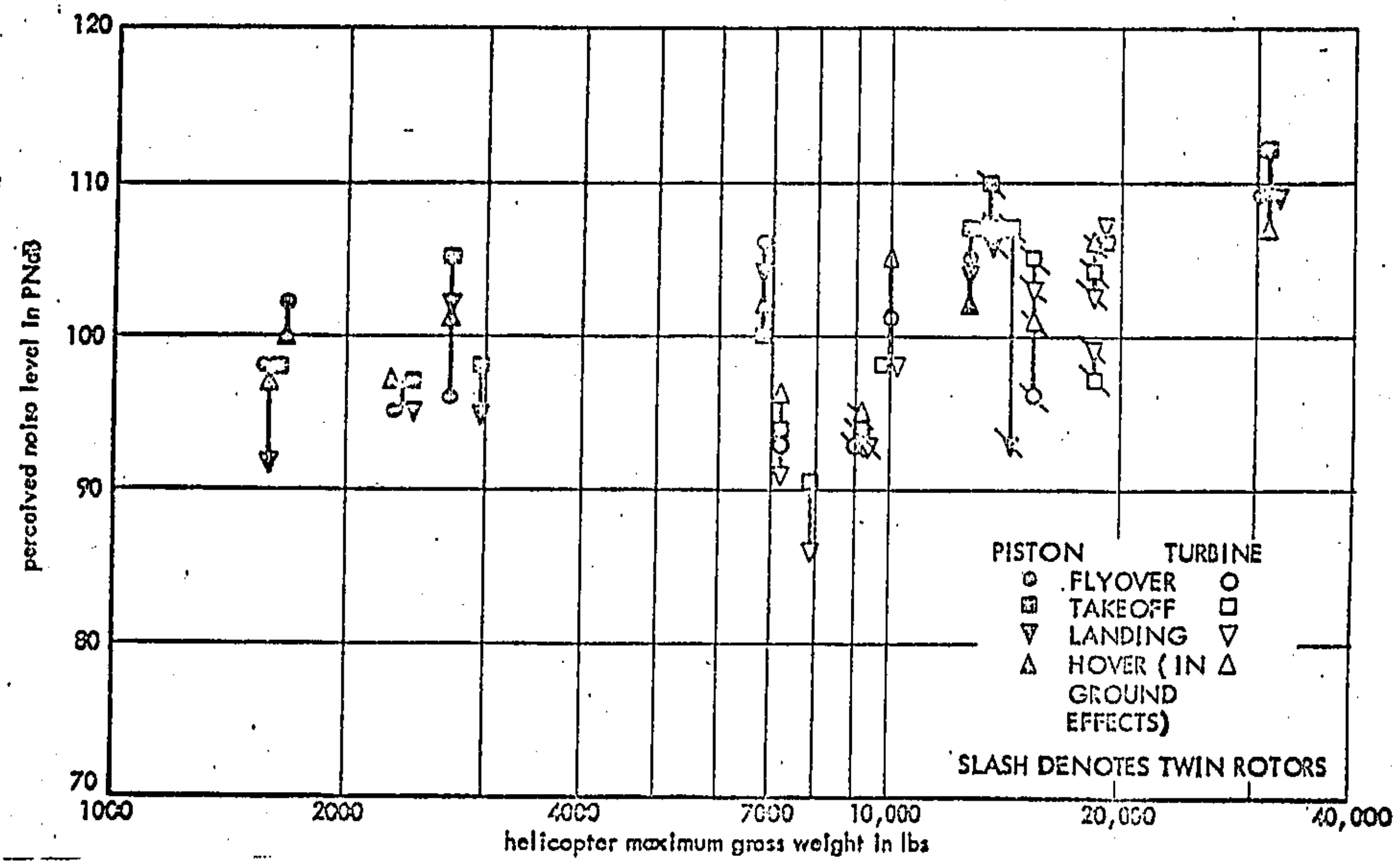

FIGURE A-1. COMPARISON OF PERCEIVED NOISE LEVELS DURING TAKEOFF, LANDING FLYOVER AND HOVER FOR DIFFERENT TYPES OF HELICOPTERS (250 FT. DISTANCE)

a) for the 17 helicopters for which takeoff and landing measurements were available, the average spread of perceived noise levels between takeoff and landing was 3.5 PNdB; for 15 of the 17 sets of measurements (88%), the spread was 5 PNdB or less

b) for the 11 aircraft having comparable takeoff, landing, and flyover data, the average spread in noise levels for the three operations was 4.5 PNdB, with 7 (64%) of the measurements showing a spread of 5 PNdB or less

c) for the 11 aircraft for which takeoff, landing, flyover, and hover data were available, the average spread in noise levels was about 5.5 PNdB, with 5 (55%) of sets showing a spread of 5 PNdB or less.

Study of the figure shows that frequently, although not consistently, the maximum noise levels were observed during takeoff operations and the noise levels were lowest during landing. One may conclude that, in general, most helicopters operate over a relatively narrow range of perceived noise levels, in distinct contrast to that observed for fixed-wing aircraft where variations in takeoff and landing noise levels of 15 to 20 PNdB are frequently encountered.

Although the perceived noise levels generally show small variations for widely different flight operations, the overall sound pressure levels or the noise levels in individual octave bands may well show a much greater spread. The perceived noise level, weighting the octave band noise measurements in terms of noisiness or annoyance, weights most heavily the noise levels in the mid-frequency octave bands. Low frequency noise levels, which may often determine the overall sound pressure level, usually contribute little in determining the perceived noise level. Thus the quite intense low-frequency noise levels, generated by the main rotor at the fundamental and higher harmonics of the blade passage frequency have little or no influence on the calculated perceived noise level.

B. Variation of Perceived Noise Level With Distance

Comparison of perceived noise level-vs-distance curves for various helicopters and for different flight operations showed that the differences in curve slopes were generally quite small. No consistent differences in the slopes of these curves between turbine or piston helicopters, or for different flight operations, were found. On this basis a single generalized perceived noise level-vs-distance curve has been established to apply to all types of helicopters and to all types of operations. This curve is the basis for the perceived noise level curves of Fig. 2.

To indicate the extent of variability among curves for different helicopters, Table A-I shows the spread in perceived noise levels about the generalized curve observed in a sampling of 20 plots of perceived noise level versus distance. The values given in the table are for curves in which the perceived noise levels were plotted with reference to noise levels at 250 ft from the aircraft.

TABLE A-I

VARIATIONS IN PERCEIVED NOISE LEVEL VERSUS DISTANCE CURVES

Distance to Aircraft, Ft	Spread in Perceived Noise Levels, PNdB	
	Referred to General Curve*	Total
500	-0.5 to +0.5	1.0
1000	-2.0 to +1.0	3.0
2000	-3.0 to +2.0	5.0
4000	-4.0 to +3.0	7.0

* See curves of Fig. 2.

C. Trends with Size and Type of Helicopter

Figure A-1 shows some interesting trends with size and type of aircraft:

a) for the piston-powered helicopters, perceived noise levels change slowly as a function of size (gross weight)

b) for the turbine-powered helicopters the change in noise levels with size is much more pronounced

c) there is no consistent difference in the noise levels produced by single- or dual-rotor helicopters.

The trend of noise levels with size (gross weight) is more clearly shown in Fig. A-2. This figure shows shaded areas defined by the range of noise levels in Fig. A-1 for take-off and flyover operations (excluding the noise levels for landing or hover operations) of turbine and piston helicopters. Drawn through the center of the shaded areas are dashed trend lines. For the piston-powered helicopters the trend line reflects a perceived noise level increase of approximately 3 PNdB per doubling of gross weight. For turbine aircraft, the rate of increase is approximately 7.5 PNdB per doubling of gross weight.

The differences in trend lines for turbine- and piston-powered helicopters, shown in Fig. A-2, result from quite different dominating sources of noise for the two classes of helicopters. Thus, the trend lines should not be extrapolated to estimate noise levels produced by future helicopters, large or small. Such extrapolation would rapidly lead to the erroneous conclusion that for very large helicopters, piston-powered aircraft would be less noisy than a turbine-powered aircraft. Likewise, extrapolation of the turbine-powered helicopter trend line to small helicopters (2000 lbs gross weight or less) would lead to estimates of noise that are probably much lower

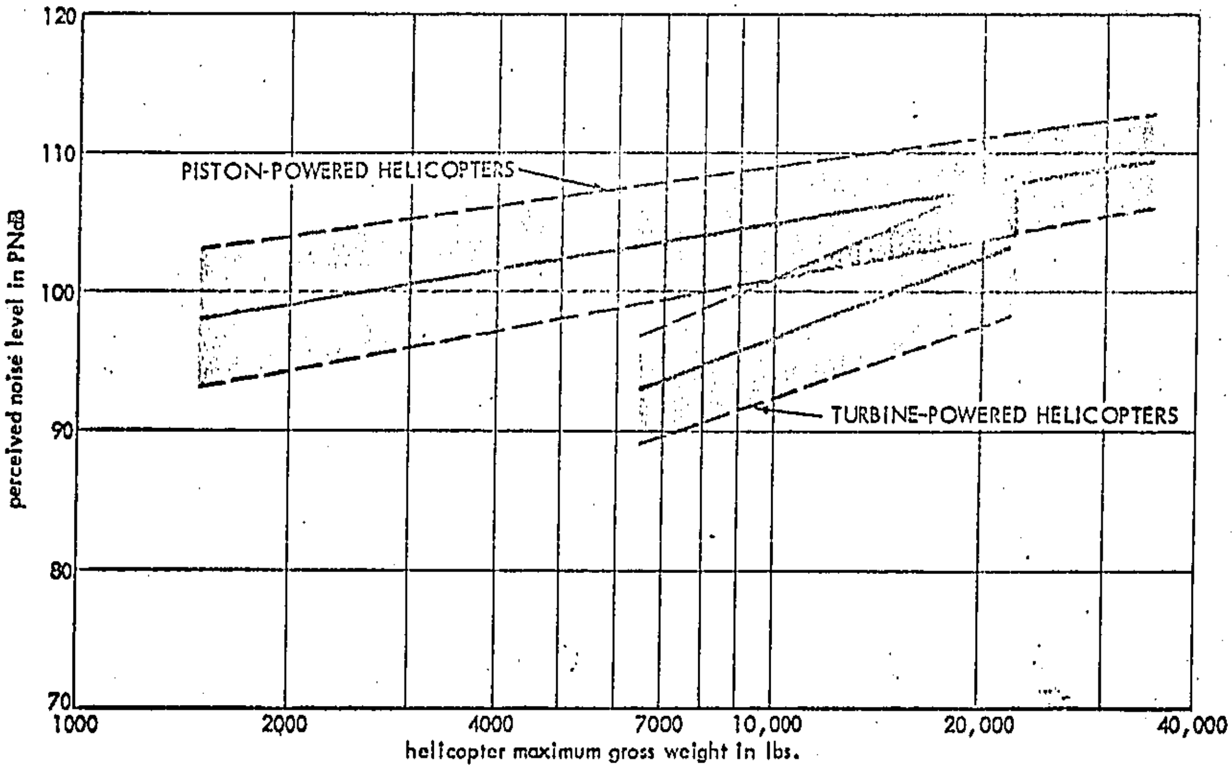

FIGURE A-2. TREND OF PERCEIVED NOISE LEVELS WITH SIZE OF HELICOPTER (TAKEOFF AND FLYOVER NOISE AT 250 FT. DISTANCE) than will actually be attained.*

Some understanding of the differences in trend lines for piston- and turbine-powered helicopters may be gained from comparison of the major noise sources for each type of aircraft. As mentioned earlier the perceived noise level weights most heavily the mid-frequency octave band noise levels. A review of the noise spectra observed at distances of 250 to 1000 ft from various helicopters shows that the octave band contributing most to the perceived noise level varied from the 250-cps octave band to the 2000-cps octave band. From previous studies of helicopter noise, the major sources of helicopter noise within this broad mid-frequency range would be expected to be those shown in Table A-II.13,14,15/ In this table the sources

TABLE A-II

PROBABLE MAJOR SOURCES OF EXTERNAL HELICOPTER NOISE IN THE 250 to 2000 CPS OCTAVE FREQUENCY BAND RANGE

Helicopter Type	
Piston Powered	Turbine Powered
Engine Exhaust	Main Rotor (Vortex Noise Component
Main Rotor(s) (Vortex Noise Component)	Tail Rotor (Rotational Noise Component)
Tail Rotor (Rotational Noise Component)	Drive System
Drive System	Turbine Compressor

* Although noise levels produced by small turbine-powered helicopters are not likely to be as low as predicted by an extension of the trend lines, noise levels for a small turbine helicopter show promise of being considerably less than those produced by current small piston-powered helicopters.

of noise are listed in estimated order of importance. Of course, for a particular helicopter, the relative order of importance of noise sources may be different than listed in the table. And, for a particular helicopter, the order of contributing noise sources may well vary for positions about the aircraft. For example, during ground hover conditions, the noise from a reciprocating engine exhaust may be much more apparent on one side of the aircraft than on the other.

For the piston-powered helicopters, assuming that the dominant noise source is engine exhaust noise, the trend with size indicated in Fig. A-2 (3 PNdB per doubling of weight) agrees well with other engine noise studies.16/ However, the trend with size for turbine-powered helicopters (approx. 7.5 PNdB per doubling of weight) is somewhat greater than expected on the basis of simple propeller theory vortex noise expressions.14,15/

D. Directional Characteristics in a Horizontal Plane

To estimate noise levels at different positions around a helicopter during ground runup or hover, one must have some knowledge of the directional characteristics in a horizontal plane. One would expect, for single rotor helicopters, a near-circular pattern due to noise from the main rotor. This circular pattern would then be modified by noise produced by the tail rotors and engines (with engine exhaust noise particularly significant for the piston-powered helicopters). Field noise measurements yield directional patterns which often show marked irregularities, particularly in individual octave bands. In terms of PNdB, the directional patterns are much less irregular but still may show distinct directional characteristics.

For example, Fig. A-3 shows the perceived noise levels at 250 ft around a small piston-powered single-rotor helicopter during hover. Two curves are shown, one for hover in ground effect and one for hover out of ground effect (aircraft at approximately one-rotor diameter altitude). Two features are evident:

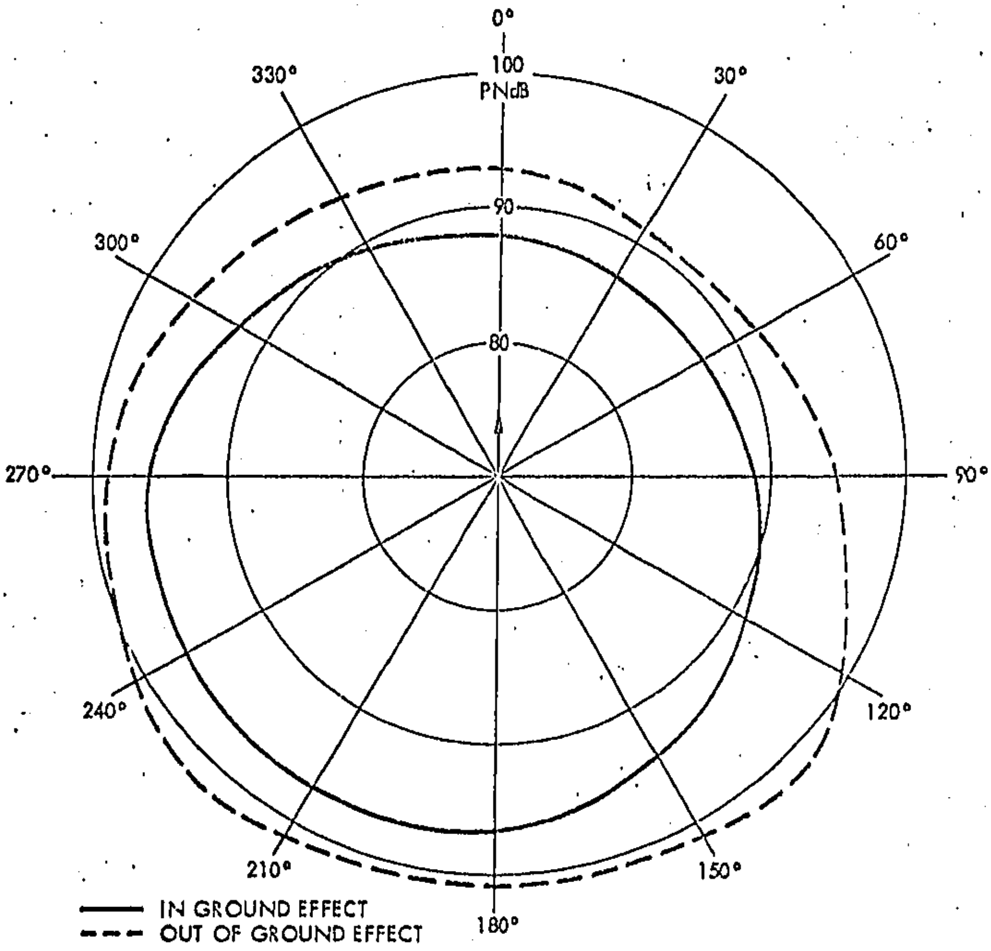

FIGURE A-3. PERCEIVED NOISE LEVELS AT 250 FT. HORIZONTAL DISTANCE AROUND A SMALL PISTON-POWERED, SINGLE ROTOR HELICOPTER DURING HOVER

a) the patterns are quite directional with maximum noise radiation between 180° and 270°

b) noise levels are from 3 to 8 PNdB higher for the aircraft hovering out of ground effect.

This rather large change in noise levels between hover, in and out of ground effect, was not observed in measurements of larger helicopters. For example, Fig. A-4 shows the perceived noise levels around a medium sized turbine-powered dual rotor helicopter. For this aircraft, there is very little change in noise levels between the two hover conditions. The pattern is also much less directional, due to the lessened influence of engine noise and absence of a tail rotor.

To avoid accounting for irregularities in the horizontal plane noise radiation pattern (usually related to details of a particular helicopter design), conservative estimates of noise levels for planning purposes may be established by assuming a uniform circular directivity pattern and assigning levels for hover conditions which are the maximum observed anywhere on a constant radius about the aircraft.

The maximum levels observed for hover (in ground effect at a 250 ft radius) are shown in Fig. A-1. As discussed earlier, these levels usually are within a few PNdB of levels observed during takeoff, landing, or level flight flyovers.

E. Directional Characteristics in a Vertical Plane

In estimating the noise levels produced by flight operations, noise levels off to one side as well as directly under the aircraft flight path must be determined. To make such estimates, some knowledge of the directional characteristics in a vertical plane perpendicular to the flight path is needed. Such a pattern is more difficult to establish from field measurements than the horizontal directional pattern. However, from analysis of noise measurements made directly underneath the aircraft and also well off to one side during helicopter flyovers at varying altitudes, the directional pattern in a vertical plane can be established.

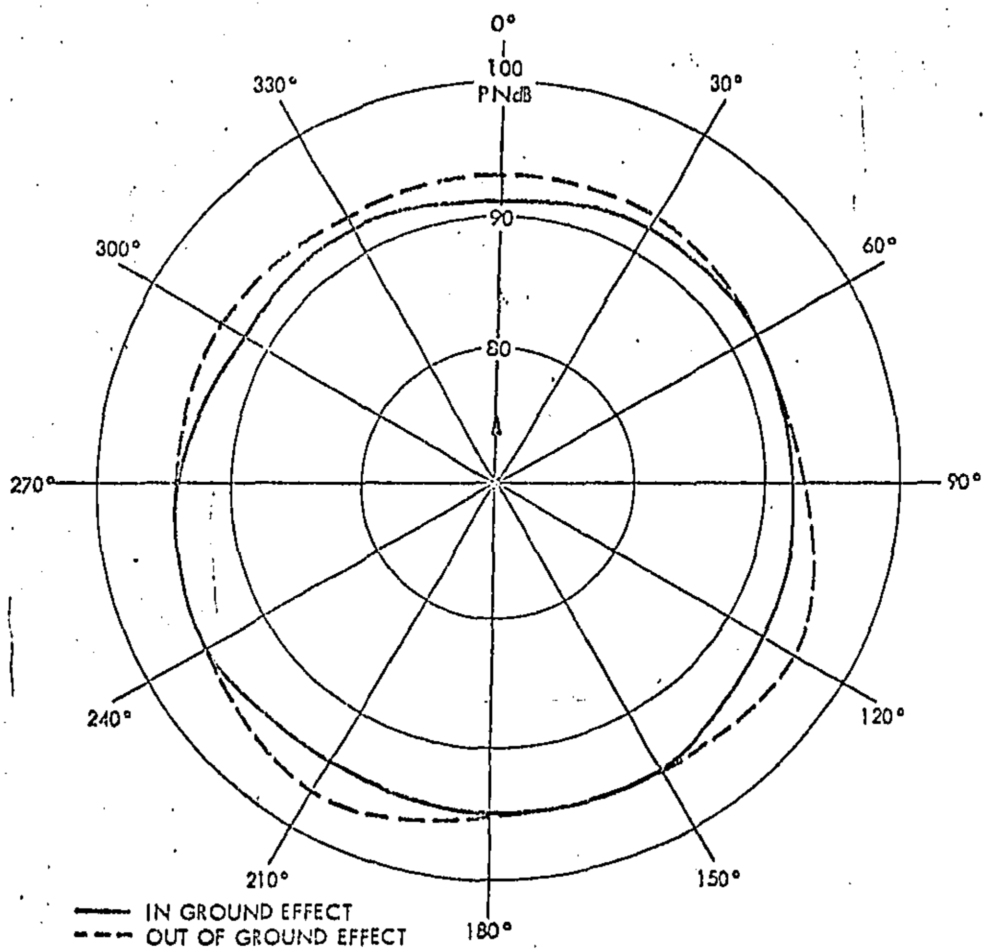

FIGURE A-4. PERCEIVED NOISE LEVELS AT 250 FT. HORIZONTAL DISTANCE AROUND A MEDIUM TURBINE-POWERED, DUAL ROTOR HELICOPTER DURING HOVER

Figure A-5 shows the approximate perceived noise level directional patterns in a vertical plane for three helicopters:

a) a small piston-powered single rotor helicopter (horizontal directional pattern shown in Fig. A-3)

b) a medium turbine-powered dual rotor helicopter (horizontal pattern shown in Fig. A-4), and

c) a medium turbine-powered single rotor helicopter.

The directional patterns for both turbine-powered helicopters are near circular. The pattern for the piston-powered helicopters shows some directionality, probably resulting from the location of the engine exhaust on this particular helicopter.*

From the patterns of Fig. A-5, and analysis of other sets of measurements, one may conclude that in estimating noise levels for planning purposes the directional pattern in a vertical plane perpendicular to the helicopter flight path can be assumed to be circular (uniform).

F. <u>Summary of Helicopter Noise Characteristics</u>

In summary, the analyses discussed in the previous parts of the Appendix show that:

---

* If the major noise source is vortex noise generated by the main rotor (the probable major source of noise for the turbine-powered helicopters), one would expect from theoretical considerations the noise levels to be a maximum when the aircraft is directly overhead. This theoretical expectation is not in clear evidence in the directional patterns shown in Fig. A-5.

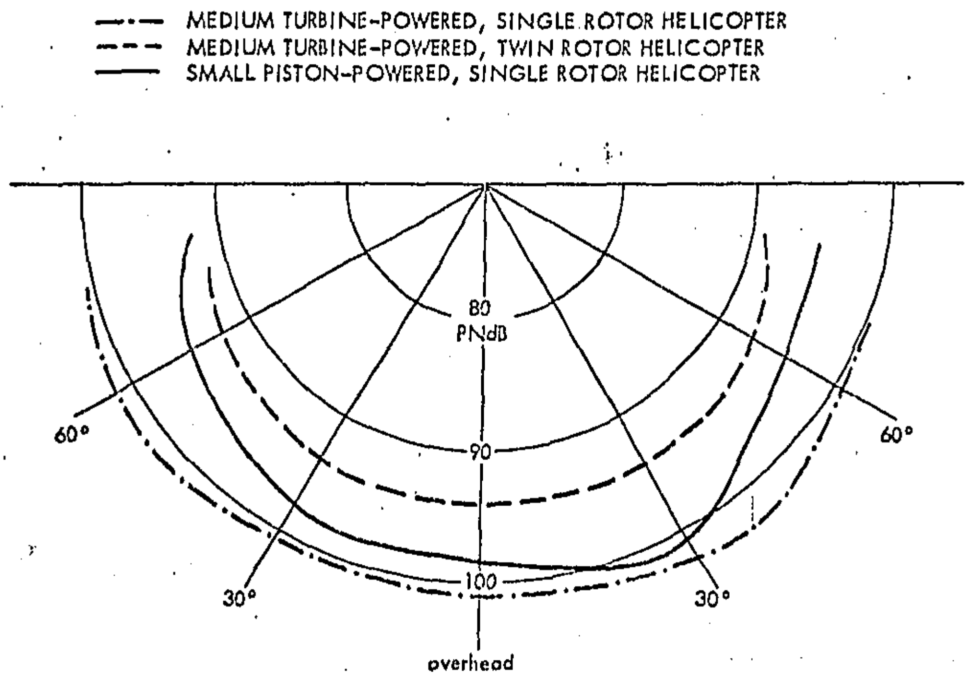

FIGURE A-5. PERCEIVED NOISE LEVELS AT 250 FT. DISTANCE AROUND HELICOPTER IN LEVEL CRUISE FLIGHT (IN VERTICAL PLANE PERPENDICULAR TO FLIGHT PATH, LOOKING TOWARD ONCOMING AIRCRAFT)

a) for a particular helicopter, the spread in perceived noise levels for takeoff, landing, cruise flight flyovers, and ground hover is quite small (of the order of 5 PNdB or less). The variations in slopes of perceived noise level-vs-distance curves for various helicopters are also quite small. Therefore, one curve showing perceived noise level-vs-distance will suffice in estimating noise levels for different types of helicopters under a number of operating conditions.

b) perceived noise levels for piston-powered helicopters are generally higher than those of turbine-powered helicopters of comparable size. For piston-powered helicopters, noise levels show a small increase with size, approximately 3 PNdB per doubling in size. For turbine-powered helicopters, the perceived noise levels show a greater increase with size, approximately 7.5 PNdB per doubling in size. No significant difference between single and dual rotor helicopters was observed.

c) noise directional patterns around a helicopter in the horizontal plane will vary with a particular type of aircraft. Conservative estimates for planning purposes can be based on a circular (uniform) directional pattern, assigning noise levels based on the maximum levels observed in field measurements made in a radius around the aircraft. These maximum levels are, generally, within a few PNdB of the levels observed for takeoff, landing, and flyover operations.

d) noise directional characteristics in a vertical plane perpendicular to the aircraft flight path can be assumed to be circular.

Bolt Beranek and Newman Inc., Los Angeles, California
HELICOPTER NOISE CHARACTERISTICS FOR HELIPORT PLANNING,
by D. E. Bishop, Technical Report, March 1965, 72 pp.,
incl. illus., 16 refs.
(Contract No. FA64WA-4949, Report No. ADS-40)

Unclassified Report

Noise data and simplified procedures are presented for estimating the perceived noise levels produced by current civil and military helicopters (piston- and turbine-powered) during takeoff, landing, flyover and hover operations. Noise data and procedures are also presented for comparing helicopter noise with other vehicle noise and with ambient noise found in typical urban and suburban areas. The procedures permit an assessment of the compatibility of helicopter noise with typical land uses near heliports.
Generalized helicopter noise data are presented in the form of noise contours and in perceived noise level-vs-distance charts for different helicopter categories. The generalized noise charts are based upon measurements of a number of military and civil aircraft. Analysis of these measurements, discussed in Appendix A, shows that:

a) for most helicopters the spread in perceived noise levels for takeoff, landing, flyover and hover operations is of the order of 5 PNdB or less, a spread in noise levels much less than encountered for fixed-wing aircraft.
b) piston-powered helicopters are noisier than turbine-powered helicopters of comparable size. No consistent difference in noise levels between single and dual rotor helicopters was noted.
c) perceived noise levels for turbine-powered helicopters show greater changes with size of aircraft than do noise levels for piston-powered helicopters.
d) for planning purposes, noise radiation from helicopters can be assumed to be non-directional in both vertical and horizontal planes.

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5. Extent of Support for Program

5.1 Can Anything Be Done About Noise?

The respondents were asked to list three noise sources that had an impact on them. They were then asked whether anything could be done about these noises. Their attitude toward this is a good index of feelings of passivity in the face of environmental invasion. The major sources of noise and the attitudes about control of those mentioning them were:

Rank	Source	Number of Items Mentioned	Percent Indicating that Control Is Possible
1	Motorcycles	44	68
2	Service Vehicles	30	57
3	People	248	50
4	Autos	205	42
5	Jets	57	23
6	Emergency Vehicles	36	14

Thus, residents feel that motorcycle noise and service vehicle noise can be controlled. They are less sure that people noise can be controlled, but are more passive with respect to auto noise, jet noise, and emergency vehicle noise.

5.2 Who Is Responsible for Noise?

Respondents indicated who they felt should be responsible for the mentioned noise sources. The noise sources and responsible parties are listed below.

		Percent Mentioning Party as Responsible			
Rank	Source	Operator	Manufacturer	Local Govt	Federal Govt
1	People Noise	33	2	52	2
2	Autos	51	18	71	10
3	Jets	18	35	25	42
4	Motorcycles	73	32	70	2
5	Emergency Vehicles	17	3	78	3
6	Service Vehicles	33	20	57	13

It must be remembered that this table and the previous one are the attitudes of those people who mentioned these sources, not of the population as a whole. Of those people mentioning these sources, however, autos, motorcycles, and, to a lesser extent, service vehicles and people noise. Jet noise is seen as a Federal Government perogative. It is clear that the majority of those mentioning any source see the local government as the most important regulating body over all sources.

5.3 Support for a Noise Control Program

Respondents were asked how much they would be willing to support a noise control program. Three questions were asked: (a) whether they would support a program, (b) how much in extra taxes they would be willing to pay, and (c) which actions they would support.

a. Support for Program: Fifty-four percent indicated that they would support a program. This is approximately twice the number of persons who were impacted by noise.

b. Extra Taxes: Again, 54 percent indicated that they would be willing to pay something in extra taxes for a noise control program, but 46 percent would not. For those willing to pay, the most typical amount was $1 per capita (which is approximately four times the present amount). Thus, residents either do not want to pay anything or else they are willing to pay quite a bit to control noise.

c. Types of Actions in Noise Control Program: The types of actions and the frequency with which they are supported are:

Rank	Action	Percent Supporting Action
1	Zoning and Planning	85
2	Fines	81
2	Public Information (tie)	81
4	Quieter Noise Source	78
5	Building Codes	73
6	Barriers	60
7	Curfews	50

Two observations from these results are: (1) the majority favor all supporting actions, and (2) the actions which are less popular are barriers and curfews.

These results give somewhat contradictory information. Results show that the majority of respondents are in favor of most actions but only a little more than half are willing to pay for and support a noise control program. Fifty percent support is probably a more realistic index of much support the city will find in the public for a program.

5.4 Support for Noise Control by Area

The frequency with which respondents favor a noise control program are:

Rank	Area	Percent Favoring Program
1	Central West (VII)	77
2	Central Northeast (V)	63
2	North Central (III) (tie)	63
4	Central (IV)	62
5	South (IX)	55
6	Northeast (VI)	53
7	Central Southwest (VIII)	47
7	West (I) (tie)	47
9	Northwest (II)	39
10	Southeast (X)	37

The most supporting areas are the central areas and the northeast. To some extent, these are the areas having poorer public services, but they are also the areas with the greatest noise impact. When support for a noise control program is compared with severity of noise as a problem, it is clear that there is a definite relationship. Residents who are impacted are more likely to support a program. It is also clear, however, from the stepwise regression, that their attitudes toward a noise control program are part of a broader perception of urban problems. Thus, noise is seen as part of a whole range of urban problems and depending on their political orientation and attitudes about attempts to handle these problems, they will or will not support a noise control program.